ABSTRACTS OF **LECTURES** AND **POSTERS**

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LECTURES
L 1.01 - The relative economic impact of drought in agriculture

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Drought results from a deficit of water that was planned to be used for some human activity; it cannot be defined in easy terms because water is a ubiquitous commodity, and because various sectors of the economy, the environment and the society at large have different vulnerabilities to water shortage. Water shortage in agriculture cannot be seen in isolation from other extreme conditions nor from competing uses and users. Nor can the cost of drought, drought preparedness, warning systems, adaptation and policy be seen in pure economic terms. This presentation attempts to look at water use in agriculture from a relatively broad perspective: there are many examples of current conflicts about water where agriculture plays a central part. In fact, it is now evident that inland water bodies as well as mountain ranges where major rivers originate may well be major areas of instability in the future. Hotspots are clearly building up, where exacerbated demand for water may eventually spill over into the social and political sphere. Even if drought, a slow onset disaster, is far less spectacular than earthquakes, volcanic eruptions or floods, its relevance to agriculture and human societies will increase dramatically in the future.
L 1.02 - Defining the drought environment: Physical and biological perspectives

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“Drought” has many meanings in relation to crop production. These meanings range from: statistical (say, the lowest decile of annual rainfall) to a meteorologist; through yield being limited by too little water to an agronomist; to sudden severe water deficits to a molecular biologist. To a farmer, the corresponding management issues, respectively, are risk management (how best to manage a meteorologically drought-prone farm over several years); how best to match cultivar and agronomic operations to the developing growing season; and how best to minimize possible major damage to (say) floral fertility induced by severe water deficits during flowering. All these definitions and the issues they imply are relevant to improving crop production when water is limiting. How can scientists best help? Answers depend on the scales (temporal and spatial) being addressed. Agronomists and breeders, interacting, can help improve components of seasonal water balance in the field, for example, minimizing evaporative losses from the soil surface or flow of water beyond the reach of roots. Physiologists can help by identifying ways of improving the competence of particular organs, for example, by identifying and ameliorating problems with rooting depths. Biochemists and molecular biologists can help by elucidating, and thence improving, cellular and molecular processes affecting especially sensitive growth stages of a crop, for example, floral infertility resulting from water deficits. Choosing tractable and important problems, that is, those whose solution will have implications in a drought-prone field environment, is both difficult and of great importance.
Precise definition of the environmental conditions and of the plant responses to those conditions is a prerequisite for the conduct of repeatable and interpretable experiments in plant water relations. The choice of measure to describe plant or environmental water status will be discussed in relation to a range of potential applications. The most appropriate choice of water status measure often differs between mechanistic studies and between them and studies concerned with practical application such as in irrigation scheduling. This paper will review and compare the range of techniques available for monitoring plant and soil water status including both conventional direct measurements of water content or energy status and various indirect approaches. An attempt will be made to identify those situations where specific approaches are likely to be most useful. The relative utility of measures of water status including those based on quantities such as water potential, osmotic potential, water content, or turgor pressure will be discussed and these direct measures will be compared with indirect measures of plant ‘stress’ based on plant responses to drought. Such indirect measures include, for example, those based on studies of stomatal conductance (for example using infrared thermography), sap flow, dendrometry or shoot extension.
The onset of agriculture in the Fertile Crescent about 10,000 years ago and its further spread modified radically the social and demographic structure of human groups, as well as their interaction with the environment, shaping the Mediterranean landscape to its present form. Dryland agriculture has been from the beginning a characteristic of Mediterranean agroecosystems. In such context, to know the temporal evolution of agriculture in the Mediterranean may give some clues on how drought has been managed over time. To that end, different methodologies developed in recent years, based on crop physiology, ecology and molecular biology, have been very helpful in reconstructing climatic and crop conditions of agriculture in the past. This lecture provide insights on the environmental conditions that characterised the adoption and further evolution of agriculture in the Mediterranean. Emphasis is first on cereals and secondly on grain legumes. Evidence is provided from the two extremes of the Mediterranean basin: Middle East and the Iberian Peninsula. A picture of the climatic context (temperature, precipitation) in which agriculture evolved, as well as the specific growing conditions (agronomic practices, water input, yields attained, breeding) is provided. Importance of a good water status to ensure crop productivity and its sustainability was already realized in the origins of agriculture. Moreover, yields attained were probably higher than those derived from gathering. Since then, Mediterranean agriculture has evolved in a climatic context that, beyond the temporal oscillations, is moving towards more arid conditions.
Growth costs water to plants. In the many parts of the world where water is in short supply, plant water use efficiency, the ratio of carbon fixation to water loss, is critical to plant survival, crop yield and vegetation dynamics. When challenged by variations in their environment plants seem to often coordinate photosynthesis and transpiration or to regulate that coordination at the expense of growth. Genetic variation in transpiration efficiency has been identified and exploited in breeding programs. Remarkably, however, that variation seems to be often associated with variation in the stomatal conductance component. This presentation will examine some advances towards unlocking the coordination between transpiration and photosynthesis and overcoming the hurdle of increasing transpiration efficiency while maintaining yield.
Irrigated agriculture has been under increasing pressure in the last three decades to respond to two perceptions that are contradictory: “The appalling waste of water by an agriculture that grows water-guzzling crops” and “The need to feed ten billion”. At present, and more so in the future, the response of irrigated agriculture in many world areas will take place under water scarcity. To cope with scarce supplies and to maximize the productivity of water (WP), deficit irrigation (DI), defined as the application of water below full crop-water requirements (evapotranspiration, ET), will become a very important management tool. While DI is widely practiced in millions of hectares for a number of reasons (e.g. from inadequate network design to excessive irrigation expansion), it has not received sufficient attention in research. There are however, very rich DI experiences in many areas that could orient future research in this field. Examples of current use of DI will be presented, and the need to investigate new approaches for the optimal management of water stress in the field will be emphasized. One such approach is that of regulated deficit irrigation, currently under consideration for widespread use in some tree crops and vines. Past investigations on empirical production functions or on more mechanistic approaches to predict crop yields as a function of ET have only partly helped in defining appropriate DI strategies under field conditions. This is because DI is a management technique that has not only biophysical components but economic, social and institutional components as well. The presentation will emphasize the need for an integrated approach to DI leading to optimizing the use of limited water supplies and of WP at various scales, from the field up to the irrigation scheme.
L 2.02 - Non-drought factors reducing yield in-dry land environments

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As rainfed crops are likely to be exposed to water deficit for at least part of their life cycle, management of the cropping system is important to improve the retention and use of soil water. While effort is made to minimize exposure to water deficit by choice of crop, maturity group and cultivar, and by management decisions such as planting time, sowing method, and level of fertility, crop yield may not be directly limited by availability of soil water per se. Nutrient requirement, subsoil constraints, soil biology, pests, diseases, and weeds may restrict the capacity of the crop to access and efficiently utilize the water resources available. Such other factors may need to be addressed first, before a response to any significant improvement in soil water availability can be attained. This paper addresses these issues in general, and in relation to three case studies: rainfed wheat-based systems in Mediterranean environments in Australia, rainfed rice-based systems in south and southeast Asia, and rainfed sorghum- and maize-based systems in semiarid tropical environments, with additional support drawn from other ecosystems where a prime example is available. In the past, more progress has often been made by addressing non-drought factors, but the priority is shifting to directly addressing issues related to water deficit. Greater returns to investment are likely there in future, but the critical importance of non-drought factors should not be ignored.
L 203 - Evaluation of wild Cicer species for resistance to drought

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Drought is the most important constraint on yield of chickpea (Cicer aritinum L.) in Central Asia, West Asia, North Africa and the Indian subcontinent. The world’s largest chickpea collections in ICRISAT and ICARDA were screened for resistance to drought and released only two genotypes, ICC 4958 and FLIP 87-59C, respectively. Nevertheless, these genotypes are far from being desirable to grow in farmers’ fields such as small seeded and susceptibility for ascochyta blight \( \text{Ascochyta rabiei} \) (Pass.) Labr. Because of a lack of promising multiple stresses resistant gene sources in the cultigens, we therefore evaluated wild Cicer species for resistance to drought.

\( \text{Cicer echinospermum} \) P.H. Davis, C. reticulatum Ladiz. as annual wild species; C. anatolicum Alef., C. microphillum Benth., C. montbretii Jaub. & Sp., C. oxydon Boiss. & Hoh., C. songaricum Steph ex. D.C. as perennial wild species were germinated in petri dishes and then transferred to pots including travertine soil. Urkutlu native landrace, Canitez 87, ICC 4958 and two mutants (M 3200117 and M 2400157) were used as checks. Seedlings were subjected to drought up to wilting. Perennial wild species were the best sources for resistance to drought due to recovering after wilting twice, and followed by annual wild types. Cultigens died due to the effects of drought. Although perennial species were the most drought resistant germplasm, they are not crossing with cultigens. As drought resistant germplasm sources, \( \text{C. echinospermum} \) P.H. Davis and C. reticulatum Ladiz. should be evaluated in order to improve drought resistance in chickpea breeding programs.
Adaptability and stability analysis of grain yield in advanced bread wheat lines for drought stress in cold and moderate dryland areas of Iran

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Wheat is the major crop grown in the Islamic Republic of Iran. The total area covered by wheat in dryland is about 3.8 to 4.2 million hectares. Average grain yield remains low because of drought, excessive cold in mountainous areas and high temperatures during late spring, and in other areas because of diseases and insect pests. After 12 years research activities in wheat breeding, DARI improved and released some high yield potential lines which are resistant to biotic and abiotic stress and well-adapted to agroecological regions of rainfed areas of Iran. In this article, we point out two newly released bread wheat cultivars. In order to study the adaptability and stability of grain yield in 16 advanced bread wheat lines, research was conducted for 3 years in 7 research stations during 1999-2002. The experiment was planned in RCB design with four replications and plot size of 7.2 m² (6 × 1.2). Combined analysis of variance showed the effect of Year × Line interaction was not significant so there was no need for stability analysis among years. On the basis of means comparison, selected superior winter lines were number 13 (Fenkang15/ Sefid), 12 (Ogosta/ Sefid) and 10 (Pvn“S”/ Chi/ Sabalan) (1997, 1922 and 1912 kg/ ha) and best facultative lines were numbers 5 and 6 (1945 and 1930 kg/ ha). In Maragheh station, another irrigated set of experiments was conducted to compute the drought tolerance indices such as STI, GMP and TOL. The vigorous line number 13 ‘Fenkang15/ Sefid’ was found more drought tolerant than Sardari (local check) but lower than Azar-2 (national check). This line produced the highest grain yield (2851 kg/ ha) in Maragheh, the typical cold station. Considering the other good agronomic characteristics, cold tolerance and resistance to diseases, grain quality (10.5-12.0% Pr.), it can be introduced to cold dryland areas and based on the results in moderately cold conditions, the facultative line 87Zhong 291 with 4167 kg/ ha has high yield potential and grain yield stability in Ilam stations, also can be introduced to semicold dryland areas.
L 2.05 - Assessing crop simulation models as a research tool for analysing crop responses to water deficit

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Crop simulation models predict crop growth and composition, yield and environmental consequences for a plant community in a field. Every day, they calculate the changes in plant status and the environmental conditions in the soil. Inputs are the soil permanent characteristics, daily climatic conditions and characteristics of the genotype. They are based on two types of equations. (i) Physical equations describe the carbon, water and heat balances of the crop. These formalisms are essentially known, and the problems associated with them are the degree of simplification which is acceptable for a given objective, and the estimation of the equation parameters. (ii) Control equations represent the responses of a genotype to environmental conditions. While some of them are well established, such as the response of phenology to temperature or the accumulation of biomass for a given intercepted light, others are not straightforward such as the responses of growth or of individual processes to water or nutrient deficits. Crop models are extremely useful to characterise the responses of an "average" genotype in a climatic series observed in one site. They have been used successfully to characterise "Target Population of Environments" across seasons for a region and to identify the most likely scenarios of stress in a site, thereby allowing one to optimise a network of experiments and to use stress indices to 'weight' the selection of genotypes. They have also a great value to predict the effects of "escape" strategies, such as changing sowing dates, plant densities or crop cycle duration. Conversely, it is still a domain of research to use crop models for interpreting the genotype x environment interactions involving more subtle characteristics of genotypes, such as responses of growth to environmental conditions or architectural characteristics. Scientific strategies to reach this goal will be presented and discussed.
Groundwater salinisation is a growing issue along European coastal areas. Salt water intrusion is caused by aquifers over-exploitation due to increasing water demand for multipurpose use. Agriculture plays a major role in water consumption especially in Mediterranean coastal areas where intensive irrigated horticulture is widespread. Increasing salinity of groundwater could affect productivity of irrigated crops and in a medium- and long-term perspective could contribute to secondary soil salinisation. Agriculture sector plays a double role, on one side is increasing pressures on soil and water resources and on the other, one has to deal, by mitigation and adaptation strategies, with damages caused by itself. Farmers are adapting to increasing soil and water conductivity by a mix of strategies that include crops and cultivars choice, rotation, irrigation methods, waters storage, waters mix and desalinisation. Any option by itself is not able to ensure to keep productivity levels and incomes. A survey of mitigation and adaptation strategies have been carried out together with a spatial extension assessment of the phenomena for some areas. Many different indicators have been proposed to assess and monitor salinisation at a European level but discussion is underway to select parameters and/or indices that could characterise, measure and monitor how the process evolve over time and space. An overview of proposed indicators will be presented.
During the past five years, we have investigated the effects of deficit irrigation (DI) applied during different phenological periods and of two crop load (CL) levels, on a mid-season maturing Japanese plum cultivar. In a four-year experiment, water was restricted during the fruit growth period, after harvest and during both periods. Savings in water applications were similar with DI applied after harvest or before and after. Water deficit applied before harvest reduced average fruit weight. Post-harvest water stress did not affect flowering, fruit set, fruit growth or yield in the short term, but in the last experimental year it reduced yield by 10% because the drought-stressed trees were smaller due to the cumulated reduction of tree growth during the four years. Deficit irrigation applied during both periods not only reduced fruit growth, but also had a greater effect on tree growth. In a second, one-year duration experiment, the interaction between high CL and moderate DI applied during the fruit growth period was studied. Fruit growth was similarly reduced by water restrictions independently of CL, but trunk growth was only significantly affected by DI in the high crop load level. Overall, we conclude that drought exposure during post-harvest, despite its moderate detrimental effect in the long term, should be considered in commercial plum orchards not only in case of water scarcity, but also as a tool to control vegetative growth. Water restrictions associated with high CL, or a mild but longer duration DI are not recommended because of the high reduction of tree growth observed in these treatments.
L 208 - Genetic analysis of rooting ability of transplanted rice (Oryza sativa L.) under different water conditions

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In water-limited lowland rice (Oryza sativa L.) production and superior rooting ability may be important after transplanting without presence of standing water (i.e. non-flooded conditions). Genetic differences in rooting ability of rice seedlings 3 weeks after sowing with their visible roots either pruned or non-pruned, were assessed by several parameters 4 days after transplanting (DAT), under flooded or non-flooded paddy fields (4 treatments in total) at Nishitokyo, Japan. Ninety-eight recombinant inbred lines from the two japonica ecotypes, a lowland variety Otomemochi and an upland variety Yumenohatamochi were genotyped with 107 SSR markers. Effects of root pruning were larger at 4 DAT while at maturity non-flooding affected more to reduce head dry weights. Otomemochi generally produced more numbers of new adventitious roots, partitioned greater proportion of biomass to roots and had greater increment of root dry weight (DRW) at 4 DAT than Yumenohatamochi, but these variety differences were less clear under non-flooded conditions without root pruning. Among 12 chromosome regions of putative QTLs for rooting ability at LOD > 2.5, a large QTL for numbers of new roots was detected around RM3335 in Chromosome 4 across four treatments, explaining 18.3 to 26.9% of phenotypic variation. Numbers of new roots had strong positive correlation with DRW, and greater DRW was associated with higher head dry weights at maturity only in the non-flooded and root pruning treatment. This study shows importance of rapid formation of new roots after transplanting and suggests possible involvement of other mechanisms for adaptation to non-flooded conditions.
L 2.09 - Effects of water deficits on soybean grown in a semiarid temperate environment of Argentina

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A potential region for soybean cultivation in Argentina is the SW of the Bs.As. province. Rainfall in this region is highly variable and evaporative demand large. Soil water content is the most variable of all the resources of the region, from one growing season to the next. Summer crops would require in some parts of the region supplementary irrigation. The purpose of this work was to study the effect of long-term drought stress on soybean growth, physiological parameters and yield. The frequent occurrence of periods with water stress in soybean production of the region is often the principal factor which limits its growth and yield. An understanding of the crop response to a range of water regimes should be useful, allowing improved prediction of crop performance in different situations. Soybean plants were grown under different levels of water stress applied at different growth stages. The experiments were conducted in the field and in the greenhouse for five years. A range of soybean cultivars from maturity group II and III were used. Plant development parameters were monitored periodically throughout the season as were several weather, soil and plant water parameters. The development of plant water deficit was followed using measurements of leaf water potential, leaf conductance and leaf relative water content. Measurements of soil moisture profiles using a neutron probe allowed to estimate the water extraction capacity of soybean. The sensitivity of the processes of leaf production, leaf expansion and leaf loss to water deficit was determined. Density and profile distribution of roots were measured.
L 3.01 - Can access to a cropping system simulator help farmers reduce risk in drought-prone environments?

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Much of Australia's cropping land is subject to intermittent drought periods and high annual variation in grain yields. The challenge for farmers is to adjust their level of investment in crop production inputs in order to avoid either over-investing in a crop with poor yield prospects or under-investing in a crop with good yield prospects. The paper describes the knowledge gained from 3 years of R&D and real world application and evaluation of an innovative internet service that sets out to reduce farmer uncertainty about yield prospects in response to management alternatives. Yield Prophet is a web-enabled user interface to the cropping system simulator APSIM. Simulation is used to integrate: 100 years of climate data from the nearest weather station; current season's on farm rainfall; seasonal climate forecasting tools; paddock specific pre-sowing soil moisture and nitrogen data; and locally derived soil-type-specific soil physical and chemical characteristics. Subscribers can enter their actual management information such as crop, variety, sowing date, nitrogen fertilizer rate and time of fertilizer application. They can then choose to generate reports that update the current status of the crop; soil moisture and soil nitrate, and provide forecasts of crop yield potential in response to alternative management scenarios. Yield prophet is currently capable of simulating wheat, barley and sorghum crops, as well as the soil water and nitrogen balance of fallows. The Yield Prophet experience is discussed in the context of recent critical analysis of the role of decision support systems in farm management.
L 3.02 - Strategies for managing scarce water resources in agriculture

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Water scarcity and drought are the main features of the dry areas and are increasingly affecting the economic development in this environment. Increasing water scarcity and competition on water in the dry areas are causing a decline in the share of water for agriculture. At the same time the demand for food is increasing. With most of the water resources in these areas tapped, the only option available is increasing agricultural water productivity. The question however is: can we increase water productivity to satisfy the increasing demand for food and at the same time ensure enough water for sustaining the resource base? This paper examines the opportunities in rainfed and irrigated agriculture as well as marginal drylands with substantial water productivity improvement potential. The paper presents examples of on-farm water management, germplasm improvement, agro management in integrated natural resource management context. Strategies to optimize water use in agriculture under conditions of scarcity and drought need be developed to maximize return per unit of water instead of unit of land and to improve local livelihoods. New policies and institutions are needed for implementing a sound water use development programs under these conditions.
L 3.03 - ‘Explore On-farm’ for North Africa

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‘Explore On-farm’ are on-farm research guidelines recently prepared by FAO for reducing the yield gap of wheat-based systems in farms through: i) increasing understanding of the crop and local environment and how they interact; ii) improving management of cropping systems and thus, sustainable yield; and iii) increasing diversification. It proposes on-farm trials for researchers and farmers working as equal partners. The trials encourage understanding and modifications in order to address local needs and circumstances. The initial published guidelines are a set of chapters each addressing an agronomic aspect of rainfed wheat production. Because of their nature, the guidelines require adaptation before their use in a different system. In 2004, ICARDA leaded the adaptation to North Africa by organizing a workshop with participants from Algeria, Libya, Morocco and Tunisia. In this region, cereal production is in decline shifting from being an exporter to current importer. The overriding problem is low rainfall, variable from season to season and erratic within seasons. Other problems include poor crop establishment and tillage methods, deficient weed control and poor seed quality. Agriculture and its problems are understood but the recommended crop management is not being used by farmers for a range of reasons, among these, the recommendations are not suitable for local conditions or farmers do not understand the yield penalty associated to their management decisions. It is expected that ‘Explore On-farm’ will help to improve technology adaptation and adoption. ‘Explore On-farm for North Africa’ will soon be available. You may find the original at:
In Sahel, interactions between genotype and environment (G x E) are often large. Because of these sizeable environment effects and interactions, the prediction of an expected yield with a linear mixed model is generally imprecise. Improving this prediction can be achieved by the modelization of the environment effect. It is then partly shifted from the random part to the fixed part of a mixed model by the use of a crop simulation model. This could not be possible with the empirical G x E interactions analysis. Unfortunately, most crop simulation models bear a number of parameters, the estimation of which requires a specific and costly experiment. As a consequence, these parameters are usually known but for a small set of reference genotypes. To overcome this problem, one can notice that multisite experiments usually share a control genotype for which parameters have already been estimated. We propose to develop as a Taylor series, the modelized response about the parameters of this control genotype. The other genotypes' parameters can then be estimated by a linear regression of the observed yields on the sensitivity to parameters; that is to say, on the derivatives of the response with respect to the parameters. We call this method APLAT for Approximation Par Linéarisation Autour d’un Témoin. On data set which consists of plant yields of groundnut genotypes, the prediction of yield by APLAT for 5 models was better than that made with the average model 4 times out of 5.
Coping with drought in agriculture of developing countries: insights from rice farming in Asia

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The economic costs of drought in rice production in Asia include not only the production loss of rice, but also the loss in production of subsequent non-rice crops that are grown on residual soil moisture. Additional economic and social costs arise from the choice of conservative production practices and from a longer-term decline in production capacity resulting from the depletion of productive assets. Estimates of economic losses resulting from drought in rainfed and partially irrigated areas of southern China, eastern India and north-eastern Thailand are obtained and farmers’ drought coping mechanisms are analyzed. Through a comparative analysis, deeper insights on factors that moderate or amplify the effect of drought on the welfare of farmers differentiated by socio-economic strata are obtained. Farm households are found to employ elaborate strategies that involve careful choice of cropping patterns, rice varieties, planting date, planting method and crop management practices. Increased dependence on wage income, asset depletion and public relief were found to be the major mechanisms used to meet the shortfall in income. The relative importance of these strategies varied across the region with asset depletion and public relief being more important in India than in China and Thailand. Despite these mechanisms, most farmers were unable to maintain their pre-drought level of consumption, especially in India. Poor and disadvantaged groups were found to bear the burden of drought disproportionately. The overall implications for technology design and for policy improvements for drought mitigation and drought relief are derived.
L 3.06 - Development of phenological-stage-specific crop coefficients (Kc) to manage deficit irrigation in agricultural production systems

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In-ground weighing lysimeters are used to measure real time crop water use during the growing season. By relating the water use of a specific crop to a well-watered reference crop such as grass or alfalfa, crop coefficients (Kc) can be developed to assist in predicting accurate crop needs using meteorological data available from weather stations. Reference evapotranspiration (ET0) can be obtained from several weather networks, however, without crop coefficients for specific crops, this information is only useful for grass or alfalfa. Five weighing lysimeters, consisting of undisturbed 1.5 x 2.0 m by 2.2 m depth cores of soil, comprise the Texas A&M Research and Extension Center - Uvalde lysimeter facility. Four lysimeters, weighing around 15,000 kg, have been placed each in the middle of a 1 hectare field beneath a linear LEPA (low energy precision application) irrigation system and used in field production. A fifth lysimeter irrigated by subsurface drip irrigation system located in a 0.5 hectare grassed area nearby was established to measure ET0. Maize, sorghum, spinach and onion were grown over the last three years in the crop lysimeters. Daily water use was measured on 5-min intervals. Results show the possibility of saving approximately 61 to 74 million m³ of water per year in the irrigated farms of the South Texas region if proper irrigation management techniques are implemented in conjunction with the newly developed crop coefficients. Crop water requirements, Kc determination and comparison to existing FAO Kc values will be discussed.
Simulation models can improve crop management and estimation of crop performances under water-limited conditions. Crop transpiration and soil water balance can be described by Soil-Plant-Atmosphere Continuum (SPAC) numerical models and for reliable simulations there is a need for a correct parameterization. Root water uptake is often modelled by means of a response function of soil water pressure head, $\alpha(h)$, as described by Feddes et al. (1978). There is a need for a proper description of the function through experimental data. With this perspective, the main objective of the present work is to define the parameters of the $\alpha(h)$ function for a sweet pepper crop, grown in field conditions in Southern Italy. The function $\alpha(h)$ can be determined from the ratio of actual to potential crop transpiration, at different values of soil water pressure head. Over a 3-week period irrigation was suspended; plant actual transpiration was measured by sap flow sensors, and the measurements were scaled-up to the field level by means of leaf area measurements. Potential transpiration was calculated by means of the Penman-Monteith equation, modelling minimum canopy resistance according to shortwave radiation. Soil water pressure head was calculated from volumetric water content and soil water retention characteristics. We present the trend of the ratio between actual and potential transpiration as a function of soil water pressure head. A linear response function is fitted to experimental data and the critical pressure head values for the crop are defined.
L 3.08 - Dual-purpose landraces of pearl millet (Pennisetum glaucum) as sources of high stover and grain yield for drought-prone arid zone environments of India

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Dual-purpose landraces of pearl millet (Pennisetum glaucum) as sources of high stover and grain yield for drought-prone arid zone environments of India. Pearl millet (Pennisetum glaucum) is valued for its grain and stover in the drier tract of northwestern India. Obviously, both grain and stover yields are evenly important considerations in adoption of pearl millet cultivars for arid zone farmers. In the present investigation, 169 pearl millet landraces were evaluated over a period of four years to study the range of genotypic variation in their yielding value for grain and stover, to examine the relationship between grain yield and stover yield of landraces and to identify the most potential dual-purpose landraces for their utilization in genetic improvement programmes. The overwhelming determinant of grain yield and stover yield of landraces was the total biomass yield in all four years. Harvest index was also positively and highly significantly associated with grain productivity in all sets of landraces (0.61** to 0.84**) substantiating that both high accumulation of biomass and its efficient partitioning are critical in determining grain productivity in pearl millet under arid zone environments. There was no trade-off observed between stover and grain yields. Stover productivity could explain up to 45% of variation in grain yield. A number of landraces were identified that outperformed check cultivars with respect to their stover and grain productivity. The situation was far greater promising for stover yield than grain yield. The ten best landraces had a greater capacity (35-175% higher) than check HHB 67 to accumulate biomass under arid zone conditions. The superiority of six of these landraces for stover yield was more than two-folds over check. The advantage of landraces with respect to grain yield was also enormous as they could produce 14-53% higher grain yield. Utilization of landraces in breeding programmes targeting north western or similar regions are discussed.
L 4.01 - Perception and long-distance signalling of stress by plants in water-scarce environments

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Plants in water scarce environments have the capacity to detect both soil and atmospheric drought. Interactions between roots and drying soil generate both chemical and hydraulic signals which move through the plant to the shoot to regulate plant growth, development and functioning. For example, only small reductions in soil moisture availability can modify the pH of the xylem sap and the shoot apoplast, thereby affecting the partitioning of the hormone abscisic acid (ABA) in the leaf. Such changes will exert control on stomatal behaviour and plant water loss, and growth and development of plants may also be affected via this signalling mechanism. ABA-based control of these variables can be enhanced by alkalisation of the apoplast, even under circumstances where the delivery of ABA to shoots is not enhanced by soil drying. Apoplastic pH can also be modified by changes in evaporative demand such that variation in apoplastic pH will allow some integration of edaphic and climatic impacts on stomata. More severe soil drying will influence the delivery of a range of hormonal signals to the shoots and in this paper we show that as the soil dries, both the ethylene and the cytokinin balance of shoots can change to impact significantly on shoot functioning and development. This paper will also highlight ways in which a range of soil conditions (e.g. soil nutrient status and rhizoflora) can modify the plant’s capacity to detect soil drying and the way in which the plant functions in drying soil. Both genetic and agronomic techniques can be used to exploit plant signalling processes to enhance water use efficiency in agriculture.
The physiological aspects of plant responses to water deficit are well known. The challenge now is to find the genetic and molecular pathways that set in motion this response and the deciding factors that determine relative sensitivities. Among the abiotic stresses, drought is, most certainly, the most difficult to model experimentally. Thus, the available data are compartmentalized as either cellular, tissue/organ, or organismic responses, impeding systems-based interpretations. We will present data on transcriptome changes in separate experimental systems to define drought-specific responses in (i) the primary maize root under well-watered and drought stress conditions (Sharp et al. J. Exp. Botany 55, 2343 [2004]), (ii) four vegetatively growing rice breeding lines (CT9993, Azucena, IR62266, IR64) that are distinguished by their relative drought tolerances, and (iii) three Arabidopsis ecotypes grown in a FACE experiment with differing responses to elevated CO2 in the field (http://www.soyface.uiuc.edu). Analysis of drought-regulated transcripts revealed structured responses of genes associated with cellular and biochemical activities in metabolism, energy, transcription, protein synthesis, defense and cell rescue, transport facilitation, and signal transduction pathways. These results were then compared with the growing databases containing transcript and metabolite profiles during drought episodes. Further analyses then focused on a comparison of gene expression changes under different abiotic stresses in an attempt to define which subsets of the responding genes identified stress-type specific reactions, as opposed to those that signified common responses to a deviation from homeostatic conditions.

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We aimed to quantify the genetic variability of the leaf growth response to water deficit in tropical maize lines, and to test whether this response has common genetic basis with silk elongation. To achieve this objective, an experiment was carried out in the P1xP2 mapping population developed at CIMMYT in which the tolerant parent maintains a short Anthesis-Silking Interval (ASI), really the synchrony of male and female flowering, under drought. Leaf growth and its response to water deficit were analysed by applying a method which combines genetic and ecophysiological modeling. The elongation rate of sixth leaves was recorded automatically in 120 RILs together with environmental conditions in a greenhouse experiment during a drying scenario, and in a growth chamber experiment in which contrasting evaporative demands were imposed to well-watered plants. Response curves of leaf elongation rate to temperature, evaporative demand and soil water status were identified individually for each RIL. An appreciable genetic variability was observed for each response. QTLs of maximum growth under non-stressing conditions and QTLs of the slope of the response to soil water potential were detected. Some QTLs of the responses of leaf growth colocalised with QTLs for ASI identified by CIMMYT from several drought field experiments. Common mechanisms of growth maintenance may therefore exist in both leaves and silks, suggesting that the responses of "source" and "sink" to water deficit may be genetically linked. If confirmed, these results will allow pyramiding favourable alleles for growth response to different organs to target genotypes that provide stable grain yield in drought prone environments in maize.
Genetic improvement of crops, whether approached empirically or strategically, depends on achieving a more optimal expression of traits throughout the crop cycle such that yield is enhanced. While new levels of trait expression may derive from crosses among conventional lines resulting in transgressive segregation of alleles, exotic parents can also be used to increase total allelic diversity. CIMMYT is exploiting potentially new allelic diversity from two sources: landraces and synthetic hexaploid wheat (SHW) which derive from wide crossing durum with the wild species T. tauschii. Crosses between elite wheat cultivars and SHW have resulted in lines with improved drought resistance, the physiological basis of which appears to be improved ability to extract water between 30-90 cm depth. Over 2,000 landrace accessions originating in hot, dry regions of Mexico were screened under extreme abiotic stress as hill plots. The best 50 of these were evaluated subsequently in small yield plots and an elite set was evaluated for performance characteristics. In heat stressed environment the best five landraces showed on average the following advantage over the two elite checks: 50% more yield, 10% kernel weight, 15% more stem carbohydrates at anthesis, and 0.3 °C cooler canopies during grain filling. Under drought yields were 7% better, biomass 17%, and canopies 0.3 °C cooler, while stem carbohydrates were not affected and kernel weights were slightly smaller. A DNA fingerprinting study of the best landraces indicated that they show large genetic distances from elite checks as well as amongst each other.
Rice yield is highly sensitive to drought stress at the flowering stage. Two major contributors to drought-induced yield loss are (i) the failure of anthers to deposit an adequate load of pollen on the stigma and (ii) the failure of the peduncle to elongate sufficiently to achieve full exertion of the panicle. To explain the behavior of the anther and the peduncle under drought stress and re-watering, we determined the status of water, carbohydrates and ABA in these tissues, and examined the metabolome, proteome and transcriptome, supported by anatomical studies. We focused initially in IR64 and Moroberekan, two genotypes that differed markedly in spikelet fertility under low water status, and on eui-10, a mutant of IR64 in which peduncle elongation after re-watering gave full panicle exertion. Marked differences were seen in the metabolism of ABA between anthers and peduncles after stress and re-watering, and these differences were traced to the expression patterns of the genes required for ABA synthesis and degradation. The more efficient release of pollen in Moroberekan compared with IR64 was tentatively associated with (i) constitutive differences in the size of apical and basal pores of the anthers and (ii) drought-inducible differences in expression of a glycoprotein that may cause pollen adhesion. Anthers and peduncles expressed five cell-wall invertase genes, all of which were down-regulated by drought and up-regulated by re-watering. These results suggest that carbohydrate entry into the anthers and peduncles is controlled not simply by supply from source tissues but also by sink strength.
L 4.06 - Control of plant water relations and water use efficiency through manipulation of ABA biosynthesis

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Genes encoding four enzymes in the pathway from zeaxanthin to abscisic acid (ABA) have now been reported: zeaxanthin epoxidase (ZEP), 9-cis-epoxycarotenoid dioxygenase (NCED), xanthoxin oxidase and ABA aldehyde oxidase. An ABA-deficient mutant has also recently been identified that is unable to produce cis or trans isomers of neoxanthin. We have previously demonstrated that NCED is a key rate-limiting step in this pathway by chemically inducing LeNCED1 expression in tobacco and then observing a 10-fold ABA accumulation in leaves (Plant J. 2000, 23:363), and we have partially complemented a null mutation in LeNCED1 (notabilis) to create tomato lines with a very mild ABA deficiency (PCE, 2004, 27:459). Here we will describe physiological effects of high endogenous ABA accumulation in stressed and non-stressed tomato plants constitutively over-expressing LeNCED1 (“high ABA” plants). In these plants, ABA content in leaves, roots and xylem sap was higher than in wild-type and this led to higher turgor, reduced stomatal conductance and increased water use efficiency. When “high ABA” plants were transferred from high to low vapour pressure deficits they displayed increased guttation and flooding of leaf intercellular air spaces, suggesting an ABA-induced increase in root pressure. “High ABA” plants can be considered as drought avoiding as they conserve soil water under non-stressed conditions. Over-production of ABA had some negative effects on growth on younger plants but little effect was observed in older plants. The effects on root-to-shoot signalling and the tissue-specific manipulation of ABA biosynthesis will be discussed.
Root growth and soil water extraction patterns of wheat genotypes differing in drought tolerance

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Better understanding of root system characteristics is critical to improving crop productivity in water-limited environments. In the present study, root system development and water extraction of a stay-green, drought-tolerant wheat genotype (SeriM82), a current Australian wheat variety (Hartog), and barley cv. Mackay were compared. Single plants of each genotype were established in large soil-filled Plexiglas-walled root chambers (240 cm wide, 120 cm deep and 10 cm thick). Root system morphology and architecture were monitored using digital imaging and analysis. Soil water content in each (30 x 22.50 cm) section of the chamber, which corresponded to the digital images, was measured gravimetrically at crop maturity. The root chambers were well-watered at sowing to simulate an environment where the crop relies on stored soil moisture and experiences severe terminal drought. In all genotypes, both vertical and lateral root growth continued until late in grain filling. The total soil volume explored by roots, however, varied among genotypes due to differences in lateral root spread. The drought-tolerant wheat genotype, SeriM82, had the most compact root system, whereas roots of barley cv. Mackay occupied the largest soil volume. Observed maximum root length and root tip number per unit surface area were similar for all genotypes. Despite the smaller root system size of SeriM82, the total amount of water extracted per plant did not differ between wheat genotypes. SeriM82 extracted approximately 10% more water from the deeper soil layers than Hartog or barley. These results suggest two contrasting “strategies” to avoid drought stress: a “barley strategy” based on exploring a large soil volume and a “SeriM82 strategy” based on maximising water extraction per unit soil volume by developing a uniform and efficient root system throughout the occupied soil volume.
Decreased cytokinin (CK) export from roots in drying soil might provide a root-to-shoot signal impacting on shoot physiology. Tomato plants were grown with roots split between two soil columns. Water was applied twice daily to both columns (well-watered - WW), one (partial rootzone drying - PRD) or neither (whole rootzone drying) column. Irrigation of WW plants replaced transpirational losses, while PRD plants received half this amount. Xylem sap was collected by pressurising either de-topped roots or detached leaves using a Scholander pressure chamber. Zeatin-type CKs were immunoassayed using specific antibodies raised against zeatin riboside after separating their different forms (free zeatin, its riboside, nucleotide and O-glucoside) by means of thin layer chromatography. Whole rootzone drying decreased leaf water potential ($\Psi_{\text{leaf}}$) by circa 0.4 MPa after 2 days and decreased bulk leaf CK content and xylem CK concentration (irrespective of whether sap was collected from roots or leaves) by about 50%. PRD decreased $\Psi_{\text{leaf}}$ by no more than 0.14 MPa (2-5 days after imposing PRD) and xylem CK concentration collected from leaves changed by no more than 10%, while bulk leaf CK content decreased by 25-45%. The results suggest that leaf CK content in PRD plants may be very sensitive to small changes in leaf water status (or some other soil-drying induced change in shoot physiology). Alternatively, since PRD reduced transpirational flow (via ABA-mediated stomatal closure), total CK delivery from the roots must have decreased. Future experiments aim to distinguish the most likely cause of the lower CK status of PRD plants.
L 4.09 - Reciprocal graftings of Lycopersicon pennellii L. esculentum cv. Lukullus and the tomato mutant notabilis point out specific roles for root and shoot-derived ABA in stomatal activity control

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Abscisic acid (ABA) is not only synthesized in leaves, but also in roots and it is conventionally accepted that root-sourced ABA plays a key role upon water deficit, triggering stomatal closure in the leaves. Here, we used the ABA-deficient mutant notabilis (not) in Lycopersicon esculentum, its isogenic cultivar Lukullus (Luk) and a naturally desiccation-resistant wild relative L. pennellii (pen) to study the relative importance of leaf and root-derived ABA on stomatal closure. We conducted a series of graftings with these genotypes in all possible shoot/rootstock combinations and then imposed water stress on the plants. Measurements of stomatal conductance, transpiration and water potential were performed. The success of grafts was minimal when not was the scion or pen was the rootstock. In graftings involving a not shoot, stomatal conductance and transpiration were reduced during water stress and the recovery period if pen or Luk was used as rootstock rather than not itself. Conversely, low stomatal conductance was also observed in pen even when the rootstock was not. The not/not graftings attained the permanent wilt point in 5 days whereas not/pen survived without irrigation for 21 days. These results suggest that the genotype of the shoot determines stomatal activity under normal irrigation and that under dehydration and the subsequent recovery the control is given by a root-derived substance, which appears to be in a higher dose in L. pennellii. This opens interesting perspectives for the basic and applied aspects of water stress resistance in plants.
L 5.01 - Whole plant responses, key processes, and adaptation to drought stress: the case of rice

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Adaptation to drought stress has different meanings in agricultural and ecological contexts – in crop plants like rice, the only useful adaptations are those that allow the crop to produce harvestable yield. Rice, a small-seeded plant with common individual grain weights of only 26-32 mg, drastically prunes the number of potential grains when stress occurs, allowing production of a few viable seeds. While this response ensures reproduction, agricultural systems require a shift in its set-point. Farmers also want drought adaptation achieved through mechanisms that do not compromise yield in favorable years. This framework can help breeders discard mechanisms favoring plant survival at the cost of productivity, and focus on buffering those processes that reduce yields. The options available to plants under drought are mainly alterations in dry matter distribution or developmental rate. These adjustments take time, and cannot be assessed in rapid stress experiments. Key yield-determining processes affected by drought in rice are establishment of spikelet number, pollination and early embryo abortion. Spikelet number depends strongly on carbohydrate supply in the period from panicle initiation until heading. In contrast, successful pollination depends on interactions between C supply, per se water status of elongating tissues and hormonal balances. Early grain development is also strongly dependent on hormone balances, with continuing influence of C supply. Opportunities to improve yield under drought can be identified more clearly if we view drought responses as adaptations that ensure reproductive success via reduced grain number per plant rather than as failures of plant processes to tolerate water deficit.
L 5.02 - Root growth maintenance under water deficits: region-specific responses of the cell wall proteome

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The physiology of maize primary root growth at low water potentials has been studied extensively (reviewed in Sharp et al. 2004, J Exp Bot 55: 2343-51). The research has taken advantage of a kinematic approach, which revealed that cell elongation in water-stressed roots is maintained preferentially towards the apex (Sharp et al., 1988, Plant Physiol 87: 50-57). This system provides a powerful underpinning for functional genomics studies, and a Plant Root Genomics Consortium (http://rootgenomics.missouri.edu) has been formed to study the gene networks, proteins and metabolites involved in the regulation of root growth maintenance during water deficits. This presentation will focus on water stress-induced changes in the composition of cell wall proteins (CWP). Previous work indicated that CWP may play important roles in enhancing cell wall loosening in the apical region of water-stressed roots, thus maintaining cell elongation despite reduced turgor pressure. We are using a proteomics approach to gain a more comprehensive understanding of how CWP composition changes in association with the differential growth responses to water deficit in distinct regions of the root growth zone. As the first step, we extracted water-soluble and loosely ionically-bound CWP using a vacuum infiltration-centrifugation technique, and examined protein profiles using 2D-gel electrophoresis and mass spectrometry. The results reveal major changes in protein composition between well-watered and water-stressed roots. Protein identifications and functional analysis of the stress-induced changes will be presented, and integration of the results with microarray analysis of CWP gene expression will also be discussed.
Enhanced oxidation is a central feature of abiotic stresses, such as drought. We report the characterisation of three plant genes that are involved in the protection against oxidative stress. Firstly, a 1-Cys peroxiredoxin (XvPer1) was isolated from the resurrection plant, *Xerophyta viscosa* by differential screening. XvPer1 is a nuclear-localised protein expressed in vegetative tissues, under stress conditions. In contrast, the closest Arabidopsis homologue, AtPER1 is seed-specific and not expressed in other tissues, even under stress. Secondly, we have taken a functional cloning approach to identify novel plant genes involved in oxidative stress tolerance, using the oxidant-sensitive yeast mutant, *yap1*. In this screen, we identified a late embryogenesis-abundant (LEA)-like protein, AC3, which conferred tolerance of yeast to H$_2$O$_2$. Expression of AC3 also increased tolerance of *yap1* cells to the pro-oxidants diamide, menadione and tert-butyl hydroperoxide. Unlike most LEAs, AC3 is not seed-specific, but is highly expressed in roots and reproductive organs. Constitutive expression of AC3 was low in leaves but was strongly induced by dehydration, oxidative stress treatments and also by ABA, albeit to a lesser extent. Under dehydration stress, AC3 was induced in leaves of *abi1-1* (ABA-insensitive) and *aba1-1* (ABA-deficient) Arabidopsis mutants. We conclude that AC3 is a novel LEA that is involved in drought, but that its induction is predominantly via an ABA-independent pathway and that its role, therefore, is more closely related to protection against oxidation, rather than other effects of water deficit.
The use of deletion mutants in identifying candidate genes for drought tolerance

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Deletion mutants offer an excellent tool for studying the molecular and genetic mechanisms underlying response to drought stress. With an expected recovery rate of approximately 0.3%, high throughput screens are required to isolate variants with altered response to stress while maintaining sufficient sensitivity to detect the genetic differences between wild type and mutants. We have used mass screening for response to field drought stress, plant growth regulators, and dormancy to isolate drought tolerant variants. Six conditional deletion mutants have been identified for improved drought tolerance. These mutants have been consistently shown to continue growth and biomass accumulation during drought stress. Extensive testing under field and greenhouse conditions has been conducted to investigate physiological and morphological effects of these deletions on growth under drought stress. Hydroponic screening using plant hormones known to regulate many drought responses was also conducted. These studies will help to isolate the effects of these deletions on growth under stress and aid further work on mechanisms of drought tolerance. To investigate the deletions of these mutants, two gain of function mutants were backcrossed with the wild type and advanced to F3. Performance and yield under vegetative stress were measured and recombinants with exceptional performance selected. Segregation of progeny for all traits was observed. In both crosses there was a shift in means with greater retention of green leaf area and yield than wild type. Data from backcross suggests the mutations are dominant to the wild type allele and the two mutants have different deletions, confirming phenotypic observations.
Most agricultural crops are harvested for their reproductive structures. The development of these structures depends on photosynthesis that, when diminished by drought, can interrupt certain phases. The interruption is most severe around the time of pollination when irreversible floral abortion can occur, leading to decreased grain or fruit numbers. In maize (Zea mays L.), ovary metabolite pools are depleted down-stream of sucrose, implicating ovary invertase as a limiting step during a water deficit. The expression of ovary invertase genes (soluble and cell wall forms) decreases. Intravenous feeding was developed to supply the photosynthetic products, mostly sucrose, that the parent plant was unable to provide to the reproductive structures. The feeding recovered the expression of some of the invertase genes and prevented much of the abortion. Glucose imaging identified a steep glucose gradient between the site of invertase activity in the upper pedicel and the nucellus that diminished during water deficits and was restored by sucrose feeding. In the absence of feeding, certain genes for senescence were up-regulated but less so if sucrose was fed. These latter genes may account for the irreversibility of abortion. It thus appears that sugars provide not only carbon but also signals to genes that control the fate of flower and embryo development. The signals act in the developing flower itself while the parent plant survives, suggesting that genetic modifications might have the potential to keep reproductive structures as alive as the parent.
Reproductive development in maize under drought conditions has been extensively studied due to its economic importance. Drought causes interruptions in reproductive development, often leading to ovary abortion and thus, causing yield losses. In some respects, these effects resemble abortion caused by insufficient light. The basics lie in the delivery of carbohydrates to the developing structures by the phloem and post-phloem transport system. Even though there is an extensive literature detailing the pathways of transport and cellular processes associated with phloem unloading, there are few that explore unloading behavior when reproductive structures fail to develop. In order to study phloem unloading under these conditions, we supplied CFDA to the stems of maize when the ovaries were undergoing abortion induced by inhibited photosynthesis at low $V_{w}$ or in shade. To explore the usefulness of this dye as a tracer of the sugar stream, we compared its translocation with safranin, which is known to be xylem-mobile, and with the deposition of ovary glucose and starch, which depend on the delivery phloem-mobile sucrose. Analyses showed that both shade and low $V_{w}$ reduced the transport of carboxyfluorescein to ovaries, but the transport was recovered close to the control transport when plants were rewatered and light intensity was increased to the level of control plants. Images of maize ovaries showed that carboxyfluorescein was transported in the phloem and was located in the same structures as starch. Our results confirm the earlier suggestions that ovary abortion results at least partly due to severely impaired sugar influx.
Insights into the molecular genetics of drought resistance from one mapping population of rice

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A mapping population of F6 recombinant inbred lines (RILs) from a cross of drought resistant rice varieties Azucena and Bala produced 10 years ago was used to identify quantitative trait loci (QTL) for root morphological traits and drought avoidance using a variety of different screening systems and field locations. These data indicate these traits are controlled by many, small QTLs, suggest the presence of considerable QTL x environment interaction (different methods/fields give different QTLs) and, disappointingly, fail to provide a convincing link between root traits and drought avoidance. Subsequent field experiments on the parents, the mapping population and near isogenic lines (either derived from RILs or produced as part of a breeding programme aiming to put root growth QTLs of Azucena into Indian upland variety Kalinga III) have shown that genotypic differences in root distribution can be detected in the field, but depend on soil physical properties. Growth room experiments designed to quantify the importance of QTL x environment (soil nitrogen, soil water or light level) interaction for root traits indicate interaction is generally much less important than main effects, providing confidence on the utility of detected QTLs for breeding. Most recently, the hunt for candidate genes has begun at a few of the most promising QTLs. The strategy being used is described.
The stay-green phenotype, characterised by the retention of more green leaves and stems during post-anthesis drought, is associated with increased lodging resistance and grain yield in sorghum. The objective of an international project involving Australian and U.S. scientists is to identify and understand the function of gene networks that contribute to improved plant drought adaptation and productivity in water-limited environments, including the integration of breeding, physiology, molecular biology and simulation modelling. This paper focuses on physiological aspects of our gene discovery project, in particular, data from rain-out shelter and lysimeter studies undertaken at DPI&F’s Hermitage Research Station in southeast Queensland, Australia, during 2004. Functional understanding of the key genes in each of four QTLs associated with the B35 source of stay-green (Stg1, Stg2, Stg3 and Stg4) is sought. To this end, a total of 20 experiments have been conducted over the past five years in four target environments. Initially, genomic regions containing each of the four StgQTLs were introgressed into a Tx7000 (senescent) background by scientists at Texas A&M and Texas Tech Universities, producing near-isolines for Stg1, Stg2, Stg3 and Stg4. The overall conclusion of these studies is that stay-green is largely a constitutive trait such that the plant prepares itself to face the challenge of drought before encountering the challenge. Essentially, all of the mechanisms observed post-anthesis are the emergent consequences of physiological processes initiated prior to anthesis. The key physiological mechanisms operating before and after anthesis will be discussed.
Cassava is an important staple crop for developing regions worldwide and is valued for its reliable yield in environments subject to abiotic stresses. Although cassava is one of the best crops for drought-prone environments it is also among the most productive crops in well-watered situations. The mechanisms it uses to regulate growth and stress tolerance activities in such contrasting conditions are not well understood. The objectives of this research are to evaluate the hypothesis that cassava tolerates drought primarily by employing a conservative resource-use and partitioning strategy, accumulating carbohydrate reserves in stems and storage roots prior to a drought episode, conserving resources during stress by limiting vegetative growth, shedding leaves, and restricting root branching, such that carbohydrates are available to initiate rapid regrowth when rainfall resumes. To test this hypothesis we determined the effects of a water stress (without rewatering) on ABA, sugar, starch accumulation and partitioning in different plant parts and evaluated new adventitious root growth as affected by different water regimes. Cassava plants grown in one meter high pots were subject to four different water regimes during 30 days. Apical, basal leaves and adventitious roots were sampled during the drought episode. Leaf senescence/abscission and biomass were also quantified. Preliminary results indicate decreased transpiration due to stomatal closure at an early phase of stress, gradual accumulation of ABA and sugar accumulation in leaves during the first week. Adventitious root growth was observed in all treatments. Water stressed treatments showed more leaf senescence/abscission, less biomass when compared to controls.
Drought is the major cause of sugar beet yield losses in the UK and other areas where summer rainfall is significantly less than potential evapotranspiration. In arid regions as well as the UK, irrigation is limited because water is scarce and devoted to other crops. Within sugar beet germplasm there is genetic variation for drought tolerance, hence improved varieties can be developed if breeders are equipped to make these selections. The experimental objectives were to assess the degree of genotypic diversity for drought-related morphophysiological traits and to measure the strength of association between these traits and crop performance. Eighty three sugar beet genotypes with diverse genetic backgrounds were tested in field experiments from 1999 to 2003. Plots were either irrigated or droughted by covering plots with large polythene tunnels. There were significant genotypic differences for yield, drought tolerance index (DTI), stomatal conductance, succulence index, specific leaf weight, carbon isotope discrimination ratio and osmotic adjustment, but not for photosynthetic rate, relative water content or total water use. The maintenance of green canopy during drought showed positive phenotypic correlation with DTI, which was negatively correlated with succulence index and wilting score. Droughted sugar yield was positively correlated with deep soil water extraction and negatively correlated with relative leaf expansion rate. Genotype x trait biplots showed superior genotypes with relatively greater expression of combinations of favourable traits. The most promising secondary traits were succulence index and wilting score, which could be used to cull inferior genotypes in early stages of breeding programs.
Drought stress induces a variety of genes at transcriptional level. Their gene products are thought to function in drought stress tolerance and response. Many drought-inducible genes have been used to improve stress tolerance of plants by gene transfer. In this conference, we present recent progress on global analysis of expression profiles of drought- and cold-responsive gene expression using microarray technology, and functional analyses of stress-inducible genes in stress tolerance. We have analyzed expression profiles of the drought- and cold-inducible genes and identified at least four independent regulatory systems in stress-responsive gene expression, two are ABA-dependent and two are ABA-independent. In one of the ABA-independent pathways, a cis-acting element (DRE/CRT) and its binding proteins, DREB1/CBF and DREB2, are important cis- and trans-acting elements in stress-responsive gene expression, respectively. Based on microarray analysis, many DREB1A/CBF-target genes that function in stress tolerance have been identified. Overexpression of these genes improves stress tolerance in transgenics. Recently, we showed that one of the NAC transcription factors functions in stress-responsive gene expression. In two ABA-dependent pathways, bZIP transcription factors (AREB/ABF) and MYC/MYB transcription factors are involved in stress-inducible gene expression. We have analyzed signal transduction cascades in osmotic stress and ABA responses. Recently, we have analyzed two types of protein kinases that are involved in ABA signaling. They are a receptor like kinase RPK1 and SnRK2 protein kinases. Functions of these protein kinases have analyzed using T-DNA tagged mutants and transgenic plants. The roles of these protein kinases will be discussed in ABA signaling.
L 6.02 - Functional genomics of drought tolerance in rice: in silico gene discovery using ESTs generated from an elite indica drought tolerant cultivar Nagina 22

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Drought has become a serious constraint in rice production due to inconsistent and erratic rainfalls and a recurring drought year after year. Drought response is a complex trait in itself and is a very good model for global gene expression studies. The effective strategy to study the molecular basis of the trait is transcript profiling through generation of Expressed Sequence Tags. We present here an in silico method of identification of putative candidate genes of drought stress response in rice. We used the ESTs generated from drought stressed seedlings of an indica rice cultivar, Nagina 22 from a normalized cDNA library which greatly reduced the redundancy of transcripts (Reddy et al., 2002). The EST library included a large number of transcription factors besides novel genes. We have generated a total of 5815 ESTs (GenBank Acc no BI305180 to BI306756; BU672765 to BU673915; and CB964418 to CB967504) from this library and used to capture transcripts that will potentially lead to understanding of molecular mechanisms involved in drought stress response. The in silico analysis uncovered 589 stress responsive genes from our library. A comparative analysis of rice, arabidopsis and a few other plant ESTs was used to substantiate our functional classification and identification of putative candidate genes of drought tolerance. Interestingly the distribution of the 589 putative stress responsive ESTs among the functional categories showed that transcription factors were efficiently captured along with 192 novel genes. Also we have physically mapped all the ESTs generated along with functional annotations onto rice chromosomes, which will help in molecular dissection of QTLs of drought tolerance in rice. Gene expression profiling under field drought stress has been carried out to validate the data.

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Drought tolerance and desiccation tolerance have often been cited as manifestations of the same mechanism: desiccation tolerance being the extreme form of drought tolerance. However, there is a fundamental difference between drought and desiccation tolerance; drought tolerance mechanisms include ways of maintaining cell water content, such as osmotic regulation and stomatal closure, whereas desiccation tolerance consists of ways to survive the complete loss of water. It is clear that an evolutionary understanding of the relationship between drought and desiccation tolerance is necessary to determine which genes are adaptive in nature and which simply respond to secondary events such as cell injury. Our approach is to compare the expression profiles for genes in response to water deficits in drought sensitive species with their orthologues in desiccation-tolerant species during desiccation and within a phylogenetic framework. Our comparisons encompass a dicot to dicot pairing, a monocot to monocot pairing, and the comparison of both to the most primitive form of vegetative desiccation tolerance as manifested in the desiccation tolerant bryophyte *Tortula ruralis*. Initial comparisons between the water stress response of *Arabidopsis* and the desiccation response of *Tortula* have generated a solid baseline of similarities and differences that have generated the necessary hypotheses for our pair-wise comparisons. These data will allow us to focus attention on genes and gene networks that are truly central to cellular dehydration tolerance and may enable a more rational approach for the improvement of drought tolerance in crop species.
The Osmyb4 expression in rice is induced by cold and by pathogens. Its overexpression in Arabidopsis plants results in a significant increase in both abiotic and biotic stresses tolerance. The ability of Osmyb4 to confer a coherent phenotype in Arabidopsis, suggests an evolutionary conserved action. This idea is supported by our recent results in several crops. Here, we report the high degree of drought and cold tolerance induced by the Osmyb4 overexpression in apple and maize. We determined the relative water content (RWC) and the electrolyte leakage of wt and Myb4 expressing apple plants subjected up to 15 days of drought. A 15% reduction of the RWC was detected in control plants, whereas in transgenic leaves there was not significant reduction. The ion leakage of wt rise from the 25 (time 0) to 70%, whereas in transgenic plants no significant differences were detected. The higher osmolyte concentration (sugars and aminoacids) found in transgenic plants may be responsible of the increased drought tolerance. We evaluated the low temperature effects on respiration in vivo. For mature and young leaves of wild-type the Arrhenius plots were linear from 30 °C to 12 °C, whereas in transgenic plants they exhibited breaks at 10 °C and 6 °C, respectively. A similar effect on drought and cold tolerance was found also for Myb4 transgenic maize plants. Altogether our results demonstrated that Myb4 may induce a high level of stress tolerance, previously showed in Arabidopsis thaliana My4 expressing plants, also in crops. This, in our opinion, is of great agronomical/ecological interest.
Identification of genes for improving drought resistance of irrigated rice at reproductive stage

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Drought frequently occurs in late stages of growth and development, which causes significant yield loss. We have taken a comprehensive approach by integration of germplasm, functional genomics and genetic analysis for identifying genes for drought resistance in rice emphasizing the reproductive stage of the rice crop, which involved the following components. (1) Screening a T-DNA insertion mutant library. A total of more than 5,000 T-DNA insertion mutant families have been screened under drought conditions at vegetative or reproductive stages, and a number of mutants that were more sensitive or tolerant to drought stress have been identified. (2) Genetic analysis of drought tolerance. Using a plant-wise drought treatment of a recombinant inbred line population, drought tolerance was separated from drought avoidance, and QTL mapping results suggested drought tolerance and drought avoidance had distinct genetic basis. (3) Expression profiling for drought responsive genes. Using cDNA and whole genome oligo-chip microarray technologies, more than 900 genes were identified to be drought responsive. More than 40 drought inducible genes with known or unknown function have been overexpressed in rice cultivar Zhonghua 11 for drought stress testing. (4) Functional analysis of candidate genes. More than 10 genes that were reported to have effects on drought resistance in previous studies were tested in a common genetic background of Zhonghua 11 to identify genes conferring drought resistance at reproductive stage. (5) Root biology. Genetic analysis and QTL mapping were performed for root traits related to drought avoidance under stressed and normal conditions. Progresses have been made in all the respects of the work, which will be presented in the conference.
L 6.06 - Comparative analysis of root transcriptome changes in legumes under drought stress

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Plant root and shoot systems respond to environmental changes by altering the expression of complex gene networks through sensing environmental stresses and modification of signaling and metabolic pathways. These transcriptional changes can result in successful adaptations leading to stress tolerance. Much less is known about root biology than about the above ground parts of the plant. Also, root architecture is a critical factor in plant survival, water and nutrient uptake and can be very important in plant productivity. Drought is the major abiotic stress factor limiting crop productivity worldwide. We have studied the responses of medicago and soybean transcriptome under water stress conditions in root tissues. *Medicago truncatula* Jemalong A17 and *Glycine max* Williams 82 plants were grown in turf-face-soil mixture under controlled greenhouse conditions. One-month old medicago and soybean plants were subjected to gradual stress by withholding water and the samples were collected in three biological replicates. To quantitate the stress level we monitored relative water content of leaf, leaf water potential, and turf-face-soil mixture water potential and moisture content. Total RNA isolation, microarray hybridizations and qRT-PCR were conducted using standard protocols. We used 17K *Medicago truncatula* 70mer oligo array and the 60K soybean Affymetrix GeneChips for the transcriptome profiling. The differential expression patterns of transcripts and the regulatory networks across the legume species will be presented. Understanding the molecular regulation of root architecture and developmental pathways, and their responses to drought stress across the legume species contribute to basic root biology and translational legume biology for crop improvement.
Our work presents a functional genomics approach to dissect drought signal transduction in cereals by using *A. thaliana* as a model system. We have analysed four clones, named 6H8, 6g2, 1C1 and 10d10, previously isolated in durum wheat in response to drought using a suppression subtractive library. They showed sequence similarity with genes in *A. thaliana* never reported to be involved in stress response: a putative transmembrane protein belonging to the UPF0016 family, a RING-FINGER protein, a farnesylated protein and an E2-ligase involved in sumoylation pathway. To identify the function of these genes, two approaches are currently in progress: 1) analysis of the knock-out T-DNA mutants via a reverse-genetics approach, and 2) protein-protein interaction analysis using yeast two-hybrid system. The isolated T-DNA mutants were studied under greenhouse and laboratory conditions to test both their phenotype and stress resistance. The knock-out mutants showed a particular phenotype in control condition (20 °C, 8 h light, 150 μE) with red leaves and trichomes. In the literature it is reported that the same phenotype was shown by the wild-type in high light conditions, revealing that the red pigmentation, due to anthocyanins, is caused by ROS accumulation. To test the level of stress-tolerance of these mutants we measured chlorophyll fluorescence (Fv/Fm) in response to photo-inhibition (1 h at 2000 μE and 10 °C). The mutants showed a lower Fv/Fm than the wild-type plant, suggesting a higher sensitivity to light stress. We have also found that the mutants flower later than the wild-type plants only in short day condition. The future aim is the characterisation of the mutant plants in drought and cold stress conditions to understand the particular phenotype and the resistance. The 6g2 and 10d10 genes are putatively involved in sumoylation pathway and a protein-protein interaction study via yeast two-hybrid system has begun.
Drought and salinity are major constraints on crop production and food security, and have adverse impact especially on socio-economic aspect. Plants have developed different strategies to face water deficit and high soil salinity. Soil salinization essentially manifests as a soil water deficit; i.e. by decreasing total soil water potential ($\Psi_w$) which leads to plant water deficits. Thus, in addition to removal of sodium from cytosol through vacuolar sequestration, salinity tolerance is related to altered physiological response to plant water deficits. In a very real sense, then, physiological adaptation to low soil solution $\Psi_w$ and plant cell water deficit is a tolerance strategy to both soil water deficits and high soil solution salinity. Plants which are able to maintain photosynthesis and growth at low soil $\Psi_w$ often display a relatively greater capacity for leaf osmotic adjustment which provides a degree of cellular level tolerance to plant water deficits due to several physiological adaptations. The cloning and characterization of genes encoding tonoplast transport proteins from crop plants (H+-pyrophosphatase and an Na+/H+ antiporter), involved in the sequestration of Na+ ions into the vacuole, may contribute to our understanding of how to enhance crop plant response to saline stress. We cloned and sequenced wheat orthologs of the Arabidopsis genes AtNHX1 and AVP1 using a wheat cDNA library (accession number AY296910 and AY296911, respectively). Functional characterization of the wheat Na+/H+ antiporter TNHX1 and H+-PPase TVP1 was demonstrated using the yeast nhx1 and ena1 (plasma membrane Na+-efflux transporter) mutants (Brini et al., 2005). Transgenic Arabidopsis plants overexpressing the wheat vacuolar Na+/H+ antiporter or H+-PPase are much more resistant to high concentrations of NaCl and to water deprivation than the isogenic wild-type strains. These transgenic plants accumulate more Na+ and K+ in their leaf tissue than the wild type. Transgenic wheat plants overexpressing these two ion transporters genes are being produced. Accumulation of organic solutes due to dehydration is another mechanism by which plants physiologically adapts to plant water deficit. We cloned and characterized a novel dehydrin from wheat (Dhn5) (accession number AY619566). Subcellular localisation of Dhn5 protein localizes mainly to the nucleus. Transgenic plants overexpressing the Dhn5 are under investigation.
Cloning of genes and development of transgenic crops for drought and salinity tolerance

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Development of crop cultivars with improved tolerance to abiotic stresses is of immense importance owing to the environmental factors affecting adversely the global agricultural production. One of the immediate choices that has become available recently is the use of genetic engineering for enhancing crop tolerance to such environmental stresses as drought, salinity and temperature extremes. Nationally, few laboratories in India have developed transgenic rice and mustard tolerant to salinity stress. Efforts are in progress to pyramid genes through conventional breeding utilizing transgenic mustard through a national network for developing transgenics tolerant to multiple abiotic stresses. We have cloned several stress-related genes and promoters with an objective to deploy them in developing transgenic wheat, mustard and tomato with improved tolerance to high temperature, drought and salinity stresses. Genes that have been isolated in our laboratory include ascorbate peroxidase gene (TaApx) and genes encoding transcription factor, CBFs (TaCBF2) and TaCBF3) from a drought tolerant wheat cultivar (C306), Lea cDNA from Brassica species, codA from Arthrobacter globiformis, and otsBA operon from E. coli. Apart from these stress-related genes, we have isolated a few stress-inducible promoters for deploying them in gene stacking in developing transgenic crops with enhanced tolerance to multiple abiotic stresses. The results will be presented.
Conventional breeding approaches for drought-prone environments: an overview

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In agricultural systems, plant productivity is strongly influenced by environmental conditions and yield potential in crops is limited due to different abiotic stresses. Among them, drought is the single most important factor limiting crop yield. Breeding for drought resistance is required for both mild and severe stress conditions. This implies a need for a better characterization of the biodiversity available for drought and a deeper comprehension of the physiological mechanisms, which are crucial to assure yield when drought occurs. Traits related to drought resistance and to high yield potential should be favored in crop breeding programs. The diversity for yield performance has been evaluated under rainfed conditions and with supplementary irrigation in a set of barley cultivars in a Mediterranean environment subjected to mild drought. The results indicate that the ideotype for these environments should have minimal GxE interaction, so that genotypes with both high yield potential and stable yield would be selected. Recent developments in plant molecular biology have allowed to identify many genes involved in plant adaptation to drought. New transcription factors involved in the drought response has been identified indicating that they may play a regulatory role in drought stress response. To locate the genetic determinants for drought adaptation, a doubled-haploid barley map population has been developed with the purpose of identifying the genomic regions responsible for drought adaptation. A QTL analysis in terms of yield in drought, yield “stability” and yield reduction was performed. Several QTLs were identified on different locations of the barley genome. The most interesting locus, responsible for both yield in drought and yield stability, has been mapped on chromosome 6H. The construction of a functional map to identify candidate genes for drought tolerance has been used.
L 7.02 - Impact of selection under managed abiotic stress on performance of maize under random stress in the target environment

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Little information is available on the impact of using managed abiotic stress environments during selection of crops on breeding progress in a highly variable stress-prone environment. This presentation summarizes results obtained from a breeding program initiated in 1997 and targeted at improving maize for the stress-prone mid-altitudes of southern Africa. Maize varieties were developed in Zimbabwe using simultaneous selection in three types of environments, recommended agronomic management/high rainfall conditions, low N stress and managed drought, sampling together 2 abiotic (drought, N stress) and several biotic stress factors (maize streak virus, gray leaf spot, northern leaf blight, rust, and ear rots) relevant in southern and eastern Africa. Improved statistical design and analysis techniques and secondary traits were used to increase the precision of identifying desirable genotypes. Between 2000 and 2002, 41 hybrids from this stress breeding approach were compared with 42 released and pre-released private seed company hybrids, selected mostly under high potential conditions, in 36-65 trials across eastern and southern Africa. Average trial yields ranged from less than 1 t ha\(^{-1}\) to above 10 t ha\(^{-1}\). Hybrids from CIMMYT’s stress breeding program showed a consistent advantage over private company check hybrids at all yield levels. Selection differentials were largest between 2 to 5 t ha\(^{-1}\) and they became less at higher yield levels. The results show that including selection under carefully managed high priority abiotic stresses in a breeding program and with adequate weighing can significantly increase maize yields in a highly variable stress-prone environment and particularly at lower yield levels.
Both genetic and agronomic management strategies are required to provide sustainable impacts on reducing economic water scarcity in agriculture, maximizing extraction of available soil moisture and optimizing its use in crop establishment, growth, and production of economic yield. Integrating efficient resource management options with breeding and use of drought resistant genotypes offers the only long-term strategy to achieve this goal. Better physiological understanding of factors regulating crop growth and water use under drought stress conditions improves opportunities to devise better management strategies and identify component traits that increase the efficiency of water use and improve yield under drought conditions. Dry-down experiments were recently conducted under controlled water-deficit conditions for the physiological and genetic dissection of transpiration efficiency (TE), a major component trait of drought resistance. The genotypic variability of TE and its relationship with stomatal regulation under water-deficits were investigated in several cereal and leguminous crops, showing great potential for improvement. The incorporation of TE and the marker-assisted pyramiding of TE with other drought resistance traits in breeding populations should lead to development of new varieties with high water use efficiency under drought conditions. This paper reviews recent progress made at ICRISAT in the identification and mapping of quantitative trait loci for specific drought-resistance component traits, including panicle harvest index and yield components in pearl millet, root drought-avoidance traits in chickpea, and transpiration efficiency in groundnut. Current efforts at the Joint FAO/IAEA division for the improvement of crop water productivity and drought resistance, using carbon isotope discrimination, induced mutation and other nuclear-related techniques are discussed.
Crop biomass is linearly related to crop transpiration, because the acquisition of CO2 for photosynthesis requires open stomata, through which plant H2O escapes via transpiration. The proportionality of that exchange is WUE. Yield enhancement, via manipulation of the G, E, or GxE components of the phenotype, must necessarily increase transpiration or WUE or both. In our search for drought-tolerant soybean cultivars, we have measured actual yield (Ya) responses of hundreds of genotypes to actual (ETa)/maximum (ETm) ratios varying from a baseline ratio (i.e., ET limited to stored water plus rainfall) to a ratio of unity (i.e., replenishment of ET water loss via weekly irrigation). A genotype's season-specific maximum (potential) yield (Ym) is the Ya value obtained when the ETa / ETm is unity. Genotypic Ya is a linear function of ETa/ETm, so the linear regression coefficients (termed betas) are comparative indications of genotypic WUE. QTL analyses of several mapping populations have (so far) detected only maturity and growth morphology genes affecting (pleiotropically) beta. In more recent research, we selected 350 plant germplasm accessions originating from (and presumably adapted to) drought-prone regions of China (but still adapted to our USA test location), and 42 elite high-yielding cultivars used by soybean producers at the test location. All entries were evaluated for Ym and Ya (and thus beta) in a severe drought year (2003) and a normal year (2004). The data indicates (as we noted before) a high genotypic correlation between Ya and Ym in both drought and normal years.
Participatory plant breeding in water-limited environment

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Drought is one of the major factors limiting crop production worldwide. It is not only an exceptional event but it is a constant aspect of the agricultural systems in the rainfed areas of several regions worldwide. One of the main characteristics of drought is its unpredictability in occurrence, timing, severity and duration. In this paper we present the results of an empirical breeding program based on three principles, namely: (1) Use of locally adapted germplasm including a wild relative; (2) Direct selection in the target environment; (3) Participation of farmers in the process of cultivar development. In this program the main sources of drought tolerance is represented by lines of *Hordeum spontaneum* identified in Syria in 1987, a year with a severe drought. The materials derived from crosses with these lines entered a participatory breeding program which has now expanded to 25 villages in Syria, the majority of which are in dry areas (< 300 mm total rainfall). In 2000, a year affected by severe drought and extensive crop failure, breeders and farmers identified few surviving breeding lines all derived from crosses with the spontaneum lines identified in 1987. During 2004 and 2005, these lines have been tested by farmers under large scale in some of the driest areas of northern Syria. As several traits are associated with a better than average and consistent (over time) performance under drought, the majority of which are controlled by several genes each with a relatively small effect on the phenotype, breeding for the ability to perform consistently well over time under drought stress, can be considered equivalent to the “gene pyramiding” strategy in breeding for disease resistance. Therefore, it is not surprising that it takes a long time before a statistically detectable phenotypic effect occurs. The pyramiding of favourable alleles at the multitude of loci affecting performance under drought is currently done in participatory plant breeding programs implemented in both dry and wet sites in a number of countries, with the objective of identifying genotypes adapted to the physical environment and acceptable to the producers and the users. The understanding of the molecular mechanism of drought tolerance as well the identification of the chromosomal regions of *H. spontaneum* where most of the relevant genes are located are currently underway to speed up and to make the future selection work more precise. Considerable linkage block conservation has been observed in cultivated barley including landraces. The presence of traits important for the adaptation to low rainfall and dryland areas has been observed especially in landraces and *H. spontaneum*. However, the mechanisms of preserving adaptive gene complexes are not well understood in *H. spontaneum*. Extended characterisation of landrace and *H. spontaneum* germplasm and measurement of linkage disequilibrium is underway.
Lentil (*Lens culinaris* Medikus ssp. *culinaris*) is traditionally grown as a rainfed crop under various cropping systems that often suffer from intermittent and terminal drought. Complete crop failure has occasionally been reported in severe and prolonged drought spells. Thus, genetic improvement through breeding and selection for drought tolerance is a key issue in lentil research globally. Improving drought tolerance through genetic manipulation is based on different mechanisms, mainly drought escape and dehydration tolerance. Various strategies and approaches, and screening techniques have been adopted at the International Center for Agricultural Research in the Dry Areas (ICARDA) to identify drought-tolerant genotypes/lines. The strategy of aggregating traits for drought tolerance, such as rapid seedling growth and ground coverage, early flowering and early maturity with high biomass development have been taken into consideration during selection in drought-prone environments in farmers' fields as well as at research stations. Genotypes with long taproot and more lateral roots, traits that are directly correlated to drought tolerance, have been identified and are being used in the breeding program. Enormous variability for dehydration tolerance was noticed among landraces and breeding lines using the box-screening technique. Lines with higher developmental plasticity were identified through a study of Drought Tolerance Index using line-source-irrigation systems. Following these approaches, Lentil International Drought Tolerant Nursery has been developed at ICARDA for distribution of improved drought-tolerant lines to the national programs. Through selection in target environments, many national programs have identified and released drought-tolerant varieties for commercial cultivation.
Development of drought tolerant rice cultivars by highly efficient QTL pyramiding

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Drought is the major factor limiting rice production in rainfed areas of Asia. Developing drought tolerance (DT) rice cultivars is the most efficient way to solve the problem. In this study, we report the development of high-yielding and DT IR64 lines by QTL pyramiding. Four introgression lines (ILs) selected from BC populations each having 8–20 DT QTLs from 4 different donors (BR24, OM1723, Type3 and Hao-An-Nong) were used as parents. Two crosses were made between the ILs and advanced to F2 generation. The F2 populations were subjected to severe drought at the reproductive stage and a total of 175 DT F2 plants were selected. The selected DT F2 progeny were genotyped with polymorphic SSR markers at the target QTLs and progeny tested in replicated experiments under both stress and non-stress conditions to understand the segregation pattern of multiple QTLs in response to strong selection. Analyses of the genotypic data indicated that the donor alleles at virtually all QTL loci were favored by selection and the selected F2 progeny were homozygous for the donor alleles at most DT QTLs. Linkage disequilibrium analyses indicated that unlinked DT QTLs tended to form several association groups and QTLs within each group were strongly positively associated with one another. QTLs in different groups were either independent of or negatively associated with one another. Results from the progeny testing indicated that QTL groups acted like single genes with large effects on one or more traits (including yield) under drought. Some promising lines with significantly improved DT and yield potential were developed and will be released to farmers in the rainfed areas of South Asia.
Marker-evaluated selection (MES) is a novel approach which can detect loci that are linked to agronomically important traits without the need for phenotypic analysis. It has the power to detect loci linked to genes for drought resistance and other agronomic traits, which could be targeted in marker-assisted selection (MAS). The MES strategy uses molecular markers to track the outcome of selection in modified bulk breeding. In a rice breeding programme, selection was replicated across different rice ecosystems in eastern India and Nepal. Selection was made in close collaboration with farmers through client oriented breeding (COB). We describe the evaluation of the products from three crosses, which all had Kalinga III (an upland variety) as a common parent. The other parents were well-adapted varieties for medium and lowland ecosystems. Selection resulted in very large differences between upland and lowland types, even though they were derived from the same parents. Some have been released (e.g. Ashoka 200F for rainfed uplands) or are currently undergoing testing for release (e.g. Super 3004 for irrigated ecosystems). Thirty products were genotyped at 80 loci and shifts in allele frequency between upland and lowland ecosystems were found. The same loci showed consistently significant changes in allele frequency between these extreme environments across all crosses. MES can identify genetic ideotypes for specific ecosystems. We are currently making crosses between similar genotypes, adapted to the same ecosystem, but differing at key loci, to select ideotypes. This requires fewer generations of MAS to produce pure lines than conventional backcross breeding.
Marker-assisted farmer participatory breeding for drought resistance in rice (Oryza sativa L.)


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It requires 5-6 thousand liters of water to produce one kilogram of rice. With the objective of saving water and labor involved in rice cultivation, segregants from breeding programs involving crosses between local and improved varieties were grown in the target habitat. Water evaporated from the field and that received by precipitation was documented using a pan-evaporimeter and rain gauge respectively. Segregants from two breeding programs were grown in the target habitat under contrasting moisture regimes. F6 lines were grown during dry season 2005 in two replications with 1 IW/ CPE and 0.6 IW/ CPE. This amounted to irrigating once every 5 and 10 days, respectively. Our marker-assisted selection strategy involved 45 markers. The selection of markers has been based on our work on QTL tagging and an exhaustive survey of all published papers on QTLs associated with any trait in rice across the world. This marker-trait-database has enabled us to discern multiple trait mapped loci and possible pleiotropic effects. The data on markers is being used along with field performance to select elite lines. The mean performance of the F5 lines ranges from 17.15 to 53.43 g per plant as against the yield of IR64 (15 g). The harvest index of the transgressants was improved up to 0.48 as against IR64 (0.24 g). Five elite lines are in large-scale, multi-location trials under aerobic condition. These are higher yielding than parents and checks. Quality aspects of the lines before milling, after milling and on cooking are being given due consideration.
Wheat breeders at the International Wheat and Maize Improvement Center (CIMMYT) use a three-pronged strategy to improve wheat productivity in drought prone environments. The first approach is to select for productivity under moisture stress in well characterized environments. In this instance, moisture stress trials are sown in soils that are carefully characterized for nutrient and disease imbalances and water application is strictly controlled. The second approach targets the genetic improvement of root health, the premise being that healthy roots will use available water more efficiently. The third approach aims to improve adaptation to moisture conserving farming practices by exploiting tillage x genotype interactions. The yield performance of materials selected in this way is assessed across many environments via CIMMYT’s global wheat improvement network. The patterns of genotype adaptation across many water limited environments are then used to select parental materials and better design crosses.
L 8.01 - Marker-assisted selection for drought tolerance

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A broad set of successful backcross MAS (BC-MAS) experiments has been recently reported in crops for target traits presenting different levels of genetic complexity. BC-MAS can be a very effective approach, especially when QTL effects are stable across target environments. However, there is no doubt that the potential benefit of MAS goes largely beyond the manipulation of QTLs in BC breeding schemes, considering the nature and the amount of genetic information generated over the last decade, and the bioinformatic tools available today. The real challenge of MAS is to be able to predict which genotypes in new segregating populations have elite alleles at target loci identified through different genomics approaches, without having for example to map QTL in new cross, a very time consuming and expensive step. This approach can be conducted at target regions identified on a consensus map and allows to make genetic gain in populations developed for recurrent selection. The efficiency of this selection depends on the nature of the markers used, the size of the population, the level of recombination and the allelic composition at the target loci. Different MAS schemes will be presented, and the results of various experiments conducted at CIMMYT to improve drought tolerance in maize will be used to illustrate the benefits and limitations of the different strategies. The shift from neutral to indicative markers and the challenge of going from biparental to multiparental alleles in a segregating population to improve the efficiency of the selection will be discussed. The development of new techniques to generate and analyze data to better understand the genetic basis, and the gene interactions, for target traits/environments allows to be pretty optimistic for the future of MAS for complex traits. However, it is important to remember that plant improvement for water limited conditions remains pretty challenging due to the unpredictable rain patterns in most target environments.
L 8.02 - Increasing yield stability of corn under drought conditions: New insights from transgenic studies

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Increasing yield and yield stability under water deficit conditions is challenging due to the low heritability of the trait, the unpredictable nature of most periods of drought stress, and the need to increase our understanding of the biology. With many recent insights into the cellular mechanisms of drought stress tolerance from model systems comes the promise that biotechnology can deliver drought tolerance traits in crops, though to date, crop performance improvements have seldom been observed due to the extreme complexity and multitude of factors that influence yield. The integration of multiple stress response pathways will likely be required to significantly impact crop performance under field growing conditions. This integration of multiple biochemical and developmental pathways is approachable through the expression of transcription factors that can direct plants’ responses to drought resulting in improved plant productivity under stress. A systematic analysis of all Arabidopsis transcription factor families has revealed that single transcription factors can control complex traits (Mendel Biotechnology, unpublished). Here, we report the discovery of a role for transcription factors from Arabidopsis and corn in coordinating plant responses to drought. Our data suggest that the function of select transcription factors in drought stress tolerance is conserved across the dicot and monocot lineages due to similar impacts on specific phenotypes. In the case of the maize, the demonstration of drought tolerance has been extended from the greenhouse to the field and therefore represents a promising approach to confer drought tolerance in crop plants, one of global agriculture’s major challenges.
Previous studies with 95 bread wheat doubled haploid lines (DHLs) from the cross Chinese Spring x SQ1 trialled over 24 year x treatment x locations identified two major yield QTLs in homoeologous locations on 7AL and 7BL. The 7AL yield QTL was expressed mainly under drought conditions and the 7BL QTL under non-droughted conditions, with alleles increasing yield on 7AL and 7BL coming from SQ1 and Chinese Spring, respectively. DHLs were grouped according to those with increasing alleles for both yield QTLs (21 DHLs - high-yield group) and decreasing alleles for both QTLs (25 DHLs - low-yield group). Average yield differences between these two groups were 1 t/ha, and the yield component most strongly associated with these QTLs was grains/ear. Current work targets the primary function of these, probably homoeologous, gene(s). Comparing the high-yield and low-yield groups shows that the yield QTLs are not associated with differences in flowering time or plant height. Differences in yield between groups were associated with significant differences in grains/spikelet, biomass at maturity and anthesis, biomass per tiller, and biomass at the tillering stage. So, it is likely that the yield gene affects plant productivity in general. In one trial, flag leaf chlorophyll content was significantly higher in the high-yield group, and this was associated with differences in leaf thickness. As epidermal cell size did not differ significantly between groups, the gene for yield may affect number of cell files across the leaf mesophyll. Drought-sensitive cyclin candidate genes occur on the same chromosome 7L bins.
Water deficits are major constraints for rice production worldwide. Developing rice lines with inbuilt resistance is cost-effective method to alleviate the problem of drought. Localization of quantitative trait loci (QTLs) conferring drought tolerance will help to develop rice cultivars suitable for water scarce environments through marker-assisted selection. Numerous QTLs linked to several drought tolerance traits have been mapped in rice and a significant proportion of the phenotypic variability of several of these traits is explained by the segregation of relatively few genetic loci. However, association of these QTLs with yield under stress has to be determined. Fewer QTLs so far have been identified for rice yield and its components under drought stress in field conditions. QTLs for yield and yield components were identified from several field trials conducted in target production environment using three different populations of rice. The QTL locations viz., RG939-RG214 on chromosome 4 in IR72993-5-10-1-M x IR62266-42-6-2 doubled haploid lines, C499-PC11M1 on chromosome 2 in IR58821-2-3-B-1-2-1 x IR52661-UBN-1-1-2 recombinant inbred (RI) lines, G144 on chromosome 3, RM252 on chromosome 4, C43 on chromosome 5 and RG 341 and RG 543 on chromosome 12 in Bala x Azucena RI lines were linked to yield and its components under drought stress. QTLs for several root traits also co-located at these QTLs, in respective DH/RI lines, indicating that QTLs for root related drought tolerance traits had pleiotropic effects on yield and its components under drought stress in rice. These QTLs are being validated and IR64 root introgression lines gave higher yield under drought stress.
L 8.05 - Improving drought tolerance in maize: an industry perspective.

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Our charge in industry is to increase the productivity of maize subjected to abiotic stresses. We are using a knowledge-based approach to help us identify those strategies in both model systems and maize that provide the most potential for improving yield. The aim of our work is to develop a gene- and pathway-based understanding of the response of maize grown under unfavorable environmental conditions. In particular, we are focused on studying the mechanisms associated with the decrease in growth of the female inflorescence under drought stress. To this end, we are using both native variation and transgenic methodologies to study these mechanisms with the ultimate goal of trying to develop a more predictable improvement in the drought tolerance of commercial maize hybrids.
In previous studies we have identified a quantitative trait locus (QTL) affecting root traits and leaf-abscisic acid concentration (L-ABA) in maize; hence, the QTL was named root-ABA1. Four pairs of backcross derived lines (BDLs) were then developed; within each pair, one BDL was homozygous for the increasing allele (+) for both L-ABA and root traits and the other BDL was homozygous for the decreasing allele (-). The objectives of this study were to assess whether the QTL effects for L-ABA and agronomic performance were influenced by inbreeding level, genetic background and water regime. The BDLs were investigated both per se and in hybrid combination with unrelated testers and at varying water regimes. For both BDLs per se and hybrids, the QTL effect for L-ABA did not substantially vary depending on the genetic background; the genotype x water regime interaction was negligible or, if significant, was only due to magnitude effects. As correlated effects, the increasing allele (+) decreased stomatal conductance. For hybrids only, the (+) allele was associated to lower root lodging (on average -16%), grain yield and plant height, while an increase was noticed for flowering date; all these associated effects, however, varied depending on the genetic background, environment and occurrence of root lodging (for grain yield). In conclusion, the QTL effect proved to be rather stable for L-ABA and root lodging, while was affected by genetic and environmental factors for grain yield, plant height and flowering date.

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With publication of nearly 300 primer sequences for mapped sorghum SSR markers, and independent reports of six putative QTLs for the stay-green component of terminal drought tolerance from donor parent B35 by groups in the USA and Australia, ICRISAT initiated exploratory SSR-based marker-assisted backcrossing (MAB) to move this trait into backgrounds of diverse tropically-adapted sorghum breeding lines and cultivars to identify which of the putative QTLs most warrant applied use. Recurrent parents include ISIAP Dorado (OPV from Latin America), S 35 and IRAT 204 (OPVs from West Africa), Macia (OPV from Southern and Eastern Africa), and R 16 (fully-senescent postrainy season breeding line from South Asia). Despite considerable divergence between the donor and recurrent parents based on SSR polymorphism, numbers of available SSR markers are not yet sufficient to permit effective MAB for all six target QTLs in these elite recurrent parent backgrounds. Initial field evaluations of early generation backcross products in backgrounds of ISIAP Dorado and R 16 suggest simultaneous introgression of stg3 (linked to the recessive z gene controlling mesocarp thickness) and a second putative stay-green QTL on the same linkage group is often associated with substantial reduction in seed set that results in improved green leaf area retention at the cost of grain yield. Single-QTL introgression homozygotes evaluated to date show little improvement in green leaf area retention, and multiple-QTL introgression homozygotes exhibit sufficient linkage drag to make valid comparisons of yield performance difficult. To obtain useful introgression lines, more markers and further backcrossing are needed.
L 8.08 - Mapping Adaptation of Barley to Drought Environments (MABDE)

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MABDE is a project funded by the European Union (INCO-MED program ICA3-CT2002-10026) to understand the genetic and physiological dynamics underlying adaptation of barley to drought. The project has four components: collection of environmental, genotypic and phenotypic data into a unified database; development of appropriate statistical methods for assessing marker-trait associations; development of novel genetic materials for the analytical characterization of adaptation; and integration of the previous work towards formulation of general rules for the exploitation of naturally occurring sequence variation in breeding for adaptation to drought. A diverse collection of 192 barley genotypes (DBG) (83 landraces, 43 old varieties, 66 new varieties mainly from the Mediterranean and rest of Europe); two doubled haploid barley mapping populations (BMP) of 120 genotypes each; and a collection of 241 accessions of landraces from Syria and Jordan have been sown in 74 yield trials during the first two years of the project across the Mediterranean basin. 50 EST and genomic markers distributed across the seven barley chromosomes are used for a primary genetic analyses of all entries. The first results are confirming that the MABDE database will be a valuable tool to study drought tolerance of barley. Stable drought adaptation QTLs have been identified in both the DBG and the BMPs. A key objective of the project is to develop a functional map for the study of the drought tolerance; therefore a number of candidate genes are being mapped in the genomic areas with stable presence of QTLs in DBG and in the two BMPs.
In order to meet the challenges that drought represents for sustainable crop production, we plan to estimate the genetic diversity, at functional level, for drought tolerance in a collection of barley germplasm and then devise strategies for the deployment of useful genes in crop improvement programs. In this context, functional diversity for drought tolerance in a barley collection has been estimated at both DNA and RNA level by using gene- or EST (expressed sequence tag-derived SSR (simple sequence repeat) and SNP (single nucleotide polymorphism) markers and cDNA macroarrays, respectively. For assaying the genetic variation at DNA level, > 100 EST-SSR and EST-SNP markers have already been used with a set of 223 barley entries (comprising of landraces, modern varieties and Hordeum spontaneum) that is well characterized for drought tolerance. Fingerprinting work with more EST-SNP as well as AFLP (amplified fragment length polymorphism) markers is in progress in order to conduct LD (linkage disequilibrium)-based association mapping for drought tolerance by using genome wide scanning methodology. In the direction of functional association study, two genotypes i.e. Tadmor (drought tolerant) and ER/Apm (drought sensitive) are being used with the cDNA macroarrays. In both genotypes, two types of empirical stresses i.e. moderate and severe drought conditions are imposed on the plants at the heading stage under greenhouse conditions. For cDNA macroarray hybridization, RNA samples are being isolated from flag leaves as well as spikes from the plants of control, moderate and severe stress conditions, harvested after 2- and 5-days of imposing the drought. Thus it is possible to compare gene expression studies at different time points of drought within as well as across the genotypes. Updated results on both aspects- fingerprinting and functional genomics will be presented in the meeting.
POSTERS
P 2.01 - Effect of fertilizer management on wheat growth and yield under semi-arid conditions

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Field trials were conducted in Rafah, North Sinai desert under rain fed conditions (precipitation average <200mm). Bread wheat (Triticum aestivum) C.V. Giza-164 was grown and fertilized with three levels of nitrogen (0, 100 and 120kg ha⁻¹) and potassium at (0, 50 and 75 kg ha⁻¹) as well as their combinations. The obtained results showed that wheat leaves significantly contained greater amounts of photosynthetic pigments (chl.a, chl. b) due to fertilizers applied as split doses (5-6 times) compared to the farmer practice (2 times) or the untreated control. Wheat plants which received N at 100kg ha⁻¹ and K at 50 kg K₂O ha⁻¹ significantly surpassed the other fertilizer treatments in dry matter accumulation and grain yield. The combined fertilizer application resulted in higher grain yield ha⁻¹ compared with the single applied N or K only. The best wheat grain yield per hectare was achieved when the plants were fertilized with N at 100kg ha⁻¹ and K at 50 kg K₂O ha⁻¹. However, further applications of both fertilizers did not report significant yield increase but depressed yields. In another experiment, five wheat varieties were evaluated under rain fed conditions; viz. Sakha-69, Sakha-8, Giza-160, Giza-162 and giza-164. The results showed that wheat cultivars differed significantly in their yield characters, i.e.: 1000-grain weight, straw and grain yield ha⁻¹ and Giza-164 surpassed the other cultivars in yield. It could be concluded that dry land farming in semi-arid regions needs different management to obtain satisfactory yields to develop such areas.

P 2.02 - Response of some field crops to irrigation with secondary treated wastewater in desert soil

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In order to evaluate additional water resources under water scarce conditions, large scale field trials were conducted in virgin soil to investigate the effect of some field crops irrigation with secondary treated wastewater from wastewater treatment plant in Cairo. The trials were conducted in two successive seasons of summer 2000 and winter 2000/2001 in Berka site (virgin soil) located about 20 km north east of Cairo. Four summer crops (maize, cotton, sunflower and soybean) were rotated with other winter crops (wheat, faba bean, lupin and canola). Irrigation was carried out using surface, drip and sprinkler irrigation according to the crop. The results showed that considerable amounts of macronutrients (NPK) were applied to the grown crops during treated wastewater irrigation i.e. N (36-176%), P (72-360%) and K (99-357%) of the recommended fertilizer rates according to the crop. Heavy metals derived from treated wastewater were very small. Crop yields showed significant differences when treated wastewater was combined with the recommended fertilizer rates for most crops. Maize, cotton sunflower and wheat seemed to be better crops for irrigation with secondary treated wastewater and irrigation by surface was more efficiently used by the crops, compared with sprinkler and drip irrigation. It could be concluded from this study that it is still to early irrigation with secondary treated wastewater although it is favored for some field crops under drought conditions. From environmental and health concerns, it is preferable to use high-standard treated wastewater (tertiary treatment) even some processed crops after harvest are used.
**P 2.03 - Wheat production under water-limited sandy soil conditions using bio-organic fertilizer systems**

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Wheat crop production and improvement under unfavorable conditions is an important aim for plant breeders who are looking for genetic diversity in which stress tolerant and yield potential can be combined. Sandy soils in dry land areas are marginal for crop production. They are coarse-textured and inherently very low fertility, with very poor organic matter content and water holding capacity and high leaching rate. In Egypt, about 93% of the total area is sandy soils with organic matter less than 1%. There are many investigators who try to follow-up this problem in different ways. Two field experiments were conducted during 2003-2004 and 2004-2005 successive winter seasons in a private sandy soil farm at El-Katta Region, Giza Governorate to evaluate wheat (Triticum aestivum) performance under unfavorable conditions, production improvement, and to maximize the use of organic farming manure and discusses the agronomic aspects of adding organic and bio-fertilizers applications to soil on growth and yield parameters of some wheat varieties as a winter cereal crop. The results showed the importance of applying organic manure with bio-fertilizers compared with chemical fertilizers. The statistical analysis of data indicated that there were significant differences among the fertilizer treatments for most studied traits. The correlation coefficient between wheat yield varieties and its components was done.

**P 2.04 - Response of faba-bean (Vicia faba L.) to Orobanche crenata infestation in relation to different watering regimes**

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Pot and field experiments were carried out to investigate the effects of different watering regimes on the relationship between faba bean and Orobanche crenata and to explore the performance of some faba bean cultivars under free and infested conditions. The experiments were conducted using three watering regimes: irrigation at 20% (wet), 40% (medium) and 60% (dry) depletion of available soil moisture. Four faba bean cultivars (G.3, G.402, Assiut 104 and Cairo 241), and two infection conditions (infested and free) were used. Two pot experiments were carried out at the wirehouse of the Botany Department, National Research Centre, Cairo, Egypt. All faba bean traits were significantly decreased which coincided with decreasing the watering regimes. Orobanche spikes significantly recorded higher values under wet regimes. The faba bean cultivars behaved differently among watering regimes and varied considerably from trait to another. The extent of depression in various host traits was increased parallel to decreasing the watering regimes. Two field experiments were conducted at the experimental farm, Faculty of Agriculture, Cairo University, Egypt. The first was carried out under an Orobanche free while the second one was conducted under the infested field. Orobanche attack depressed all studied traits. Drought and Orobanche parasitism had harmful effects on faba bean crops. The application of irrigation when depletion 40% of the available soil moisture content exhibited proper regime for obtaining reliable seed yield with suitable seed chemical constituents for faba bean production. Furthermore, this regime will reduce the infestation rate of Orobanche more than wet regime when using tolerant genotypes whenever the soil is infested by Orobanche crenata.
**P 2.05 - Evaluation of lines coming up from landrace spring wheat with respect to resistance drought stress**

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One of the most important ways of breeding for increasing yield is using varieties resistant to drought. For finding lines resistant to drought, 24 lines coming up from landrace, two landrace Yazlegh 1 and 2 and four improved varieties were evaluated. This experiment was conducted at the research station of the Faculty of Agriculture, Islamic Azad Shabestar University in 1997, using a Rectangular Lattice Design 5 x 6 with two replications in normal and drought stress conditions. In this experiment, 17 traits were studied. Results showed significant difference between genotypes in most traits in both conditions. This shows that there are significant genetic differences among studied genotypes. The correlation between Yp and TOL was positive but the correlation between Ys and TOL was negative. The simple correlation coefficient STI with Yp and Ys with values 0.733, 0.891 were known. Cluster analysis, based on Ys, Yp, STI, TOL and SSI categorized genotypes into four groups.

**P 2.06 - Effect of irrigation water quantities on consumptive use, water use efficiency and crop coefficients of sesame (Sesamum indicum L.)**

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Sesame was grown for two successive seasons (2001/2002-2002/2003) at Shambat, Sudan (Latitude 15° 40/ N and Longitude 32° 32/ E) in a clay soil, montmorillonitic, with 48-54% clay, 25-29% silt, 17-25% sand and pH value of 7-8. The aim of the study was to investigate five irrigation water quantities, viz 750, 650, 550, 450 and 350 mm on actual evapotranspiration (Etc) as compared with estimated evapotranspiration using Penman-Monteith method, modified Penman formula and pan evaporation. Water use efficiency and crop factors were calculated. The best water use efficiency was obtained under irrigation water of 650 mm. Under all irrigation treatments, there was a large deviation of pan evaporation, modified Penman and Penman-Monteith estimate from actually measured evapotranspiration. Crop coefficients were decreased with lowering water quantities and with pan evaporation than with modified Penman and Penman-Monteith formula in all irrigation treatments.
P 2.07 - Effect of deficit irrigation on sugar beet under furrow irrigation method

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The agricultural sector in Iran is one of the most important economic sectors of the country, and water is the most limiting factor for production. In this situation, deficit irrigation becomes a necessity. While yield loss will occur in water-short situations, the amount of yield loss and accompanying quality problems sustained can be minimized using proper deficit irrigation management techniques. This study was conducted to determine the effects of deficit irrigation in furrow irrigation method, on water use efficiency, percentage of sugar, root and sugar yield of sugar beet. This experiment was conducted in a randomized complete block design with three replications in 1997-1998 at Kaboutarabad Research Station in Esfahan, Iran. The irrigation treatments were three different amounts of irrigation water (100, 85, and 70%) of crop water requirement. The amount of evaporation from class A pan, water use, root yield, percentage of sugar and sugar yield were measured. Experimental results showed that there was no significant difference between sugar yield of irrigation treatment. The effects of irrigation treatment on water use efficiency, root yield and sugar percentage, were significant at P = 0.01. The yield of complete irrigation treatment (52 t/ha) showed best results and the yield of irrigation treatment with 70% of irrigation water (45.5 t/ha) showed less results. Water use efficiency in full irrigation and 70% treatments were 3.71 and 4.55 kg/m³, respectively. Thus, during water scarcity, deficit irrigation techniques can be used to conserve water.

P 2.08 - Yield comparison of different clover species under water stress in Shahrekord

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A field experiment was carried out to investigate the growth pattern of different clover species under water stress at the University of Shahrekord, Iran. A split-plot design with two irrigation regimes (one and two times per week) as main-plot and 15 clover species as sub-plot with three replications was used for the study in spring 2004. The data were collected at two harvests (cuts), therefore analysis of variance were performed as split-split-plot design. Dry shoot weight and plant height of each treatment (0.5 x 0.5 m²) were taken at 2 harvests (cuts), about the time of initial blooming. The results showed highly significant differences (P = 0.01) between irrigation regimes, clover species and different harvests (cuts). The interactions between all treatments were also significant (P = 0.05) in all aspects of clover growth. Under water stress, dry shoot weight and plant height of clovers decreased up to 1.5- and 1.4-fold, respectively. Maximum dry shoot dry weight up to 2-fold, and minimum dry shoot weight were observed in Trifolium alexandrinum (originated from Isfahan) and local clover of Kordistan, respectively. Plant height of Trifolium alexandrinum (originated from Tehran) increased 6-fold taller than Trifolium subterraneum. At first cut, shoot dry weight was greater up to 1.3-fold and plant height was taller up to 1.4-fold compared to second cut. Shoot dry weight and plant height of clover species decreased under water stress but the rate of reduction is varied among different clover species.
P 2.09 - Water for life, Pakistan perspective

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The amount of water in the world is finite. The number of people is growing fast and their water use is growing even faster. A third of the world’s population lives in water stressed countries now. By 2025, this is expected to rise to two-thirds. The UN recommends that people need a minimum of 50 liters of water a day for drinking, washing, cooking and sanitation. Our objective was to highlight the issues related to fresh water in Pakistan.

Methods: Interviews with officials in government, civil society organizations and field studies. Findings and Recommendations: According to a study by the UK’s Keele University, Pakistan stands at sixth position in the world in regards to water scarcity. The UN says more than 1.1 billion people around the world lack safe water and 2.4 billion have no access to sanitation, leading to over 3 million deaths every year. Almost one-fifth of all children lack even the bare minimum of the safe water they need to live. Problems such as steep drops in the size of Asia’s Aral Sea, Africa’s Lake Chad and Iraq’s Marshlands, the deterioration of coral reefs and the rise of coastal waters because of climate changes have led to the present water scarcity. Pakistan’s per capita water availability has declined from 5,600 cubic meters at the time of independence in 1947 to 1,200 cubic meters in 2005. It is expected to reach the threshold level of 1,000 cubic meters before 2010 or even 2007. The city of Karachi and its vicinity have been facing water shortages very frequently in the last decade and the situation is growing worse. It is estimated that by 2010-2012, there could be a severe water shortage. According to an official estimate the total requirement for Karachi is 700-800 million gallon per day but it is getting only 435 million gallon per day. There is no second opinion other than the installation of a desalination plant for the city of Karachi. Desalination seawater now costs far less than in the past. It may be recalled that early this year China repeated its offer of making low cost desalination technology available to Pakistan. The Pakistan government should lose no time in accepting this offer.

P 2.10 - Growing sugar beet (Beta vulgaris L.) in soil columns at different moisture

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Drought is a growth-limiting factor for the sugar beet crop, of increasing severity in recent years. Plant nutrition is also influenced, especially in the case of nitrogen, a nutrient with a contrasting effect on yield and quality of the sugar beet. To better investigate plant performance in response to varying soil water content, 20 plastic tubes (ø 48 cm; h 160, with side openings) were filled with a soil/ sand mix, in order to grow single beet plants under a rain shelter. Three water regimes were compared: no stress, mild and severe stress in the first year (2004); no stress, early and late stress in the second year (currently under way). A $^{15}$N-enriched fertilizer was applied in order to assess nutrient efficiency under the three regimes. Soil moisture was monitored along soil profile during plant growth. In the first year, soil moisture was well-differentiated at harvest, while an unexpected decrease in the no-stress regime had required a mid-season adjustment in water supply. Dry yield of whole plants, roots and sucrose were significantly higher in no and mild stress, than in severe stress. Conversely, water use efficiency increased three times between no and severe stress, on the basis of both total dry matter and sucrose: this coincidence suggests that the plant can make a better use of limited moisture, but cannot turn a proportionally-larger share to the benefit of the commercial product. Nitrogen utilization efficiency was insignificantly raised by decreasing moisture, while labelled-fertilizer N-recovery was strongly depressed: it is perceived as the stressed plant curbs N-uptake to the detriment of applied fertilizer, while relying on soil reserves for most of its needs.
P 2.11 - Spatial and temporal variability of durum wheat water uptake: field study and simulation approach

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Spatial variation in soil water is often the cause of crop yield spatial variability due to their influence on the uniformity of plant stand at emergence and for in-season stresses. Process oriented crop simulation models, such as the CERES model (Ritchie et al. 1985), have the capability to integrate the effects of temporal and multiple stress interactions on crop growth processes under different environmental and management conditions. The objectives of this study were: a) to assess causes of yield variability at field scale; b) to understand water stress effects on grain yield; c) to spatially validate CERES-Wheat crop model. A field-scale experiment was carried out on durum wheat at the Experimental Institute for Cereal Research located in Foggia, Italy. The 3 ha field selected a predominant clay-loam soil with calcareous area well defined. Soil water content was measured every fortnight for the soil profile using the gravimetric method. Spectral measurements were made with a handheld multispectral radiometer MSR5 (Cropscan Inc.). The rather small number of samples collected throughout the season was sufficient to allow the identification of zones of similar reflectance within the field where the model was executed. Above average temperatures in December coupled with extremely dry weather conditions caused the crop emergence and plant population to be highly variable in space and time. Plant population varied from 360 to 480 plants m⁻². The area with a lower potential extractable soil water emerged on December 20 while the rest of the field emergence occurred on January 3. These differences were due to the different soil water content at planting. Soil water content varied highly both in space and time. Soil water content was initially higher in the area where the crop emerged first. This area was characterized by high active and total limestone content as well as a lower clay percentage compared to the rest of the field. Seed emerged earlier here due to a better seed-soil contact, a crucial condition for good seed germination. After the first big rain that occurred in January, the presence of calcareous and lower field capacity caused this area to have lower soil water content. The soil water content change for the soil layer 0-15 cm that occurred between January 26 and February 3 was negative, demonstrating a higher water uptake by the crop in the area where the crop emerged earlier. The area where plants emerged later showed a negative soil water content change between March 23 and April 10 compared to the area that had an early emergence. Crop growth and development were highly influenced by limited water supply throughout the season. When site-specific soil and plant inputs were used in the simulation runs, the model was able to closely predict the yield. The RMSE for the model performance was 0.2 ton ha⁻¹.
P 2.12 - Comparaison of agronomic, morpho-physiological traits and grain yield for a panel of durum and bread wheat under water-limited conditions

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In the context of the European INCO-MPC project “TRITIMED” a large panel of bread and durum wheat grown in semi-arid conditions will help assess consequences of crop strategies on yield building and drought impacts. Experiments are carried out in different environment (three countries: Italy, Tunisia and Syria, with and without irrigation) during three growing seasons. The results will provide a better understanding of the mechanisms involved in the relationship between weather, water deficit, biomass production and grain yield and its components. Also mechanisms and consequences on production have to be related to rainfall probability, climatic scenarios and their probability of occurrence for each climatic area. The expected results will contribute to the selection of traits to look for in order to reduce grain yield variability in the various environments. The experiments and the analyses will provide information generally applicable to cereal crop production in the large areas of the world where production is severely limited by drought.

P 2.13 - Impact of drought on a steppe of Stipa tenacissima in southern Tunisia

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The steppes of southern Tunisia have undergone a long intensive and irrational exploitation conjugated with climatic and edaphic aridity. These factors have led to the actual steppes’ degraded state. Indeed, the unpredictability of rains and dry year successions constitute the most prominent features of the climatic aridity in this region. The last drought that the south of Tunisia has suffered is the one which has prolonged for five years (1999-2005). he present work was carried out aiming at quantifying the impacts of droughts on the steppe of Stipa tenacissima in the chain of Matmata assessing the different constrains effect and disruption on these phytocenoses’ evolution. The main environmental changes that have occurred are therefore mainly due to human pressure and resources mismanagement rather than unfavourable climatic conditions. Hence, human activities are chiefly responsible for the environmental imbalance which has occurred in southern Tunisia.
P 2.14 - Survey of the dynamics of root system of three autochthonous pre-saharan Tunisian trees: Acacia raddiana Savi., Ceratonia siliqua L. and Juniperus phoenicea L.: Implication for their multiplication in nursery.

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The present study was carried out aiming at investigating the root system of three local pre-saharan Tunisian trees: Acacia raddiana Savi., Ceratonia siliqua L. and Juniperus phoenicea L., cultivated in rhizotrons. These species present a high economic and ecological interest in southern Tunisia. It has been shown that root development of the three species was fast, since the first months following their germination (in November), even though the growth of Acacia raddiana rooting system has been negatively influenced by the low winter temperature. Such behaviour, which constitutes, in the natural conditions, one of the adaptive features of the studied species to climatic aridity conditions, should be taken in account in case of raising of seedlings in nurseries. The very high significant positive correlations, observed between growth parameters of both the aerial and the underground parts of the three species, show that it is possible to appreciate the importance of the development of their rooting system linking the growth of their aerial parts. In practice this interrelationship enables to assess the breeding period of seedlings in nursery by estimating their root development on the basis of a simple observation of their aerial parts.

P 2.15 - Effects of water status, nitrogen supply and genotype on WUE and NUE in durum wheat

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In Mediterranean conditions, water stress and nitrogen availability are the main constrains on wheat yield. The effects of water status and nitrogen supply were studied in durum wheat (Triticum turgidum ssp durum) under greenhouse conditions. Plants of four varieties (Lahn-Haucan, Mexa, Omrabi-3, Bicrecham-1) showing contrasting yield and grain protein content in field conditions were grown in sand pots. Three water levels (40, 70 and 100% container capacity) and two nutrient concentrations (complete Hoagland and diluted ¼) were assayed. Daily evapotranspiration, water and nitrogen supply were controlled during the experiment. Total biomass was collected about two weeks after anthesis and then water use efficiency (WUE: dry matter/water) and nitrogen use efficiency (NUE: dry matter/N applied) were determined. Leaf gas exchange were measured in the flag leaf prior to harvesting and then instantaneous WUE (A/g) was also calculated. As expected, both water regime and nutrient level had a strong effect on biomass and NUE but not in WUE. Preliminary results show a tight relationship between instantaneous WUE (A/g) and integrated WUE (Biomass/ Evapotranspiration) in all studied varieties. Differences between varieties were also significant for NUE and WUE. Omrabi-3 presents higher NUE and WUE (both integrated and instantaneous), root biomass and lower shoot/root ratio and spike dry weight than the other three varieties. Furthermore, in field-grown conditions, this variety presents higher grain protein content but a lower yield. Lahn-Haucan, Mexa and Bicrecham-1 behave similarly in the greenhouse although they present markedly differences in yield and grain protein content in field conditions.
P 2.16 - Soybean water use and yield under irrigation and different row spacings

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In the SW of the Buenos Aires province, Argentina, the normal rainfall for the growing season of soybean is less than that required for high levels of crop production. Therefore soybean is greatly dependent on water stored in the soil profile or on irrigation. The objective of this work was to determine the effect of different row spacings on crop water use and yield of irrigated soybean. Several experiments were carried out at the Lower Valley of the Colorado River (39°23' S 62°37' W) on a sandy loam soil to study the water status of soybean plants under different row spacings (20, 35, 50, 70 cm). Leaf water potential, stomatal conductance and leaf relative water content were determined to evaluate the plant water status. Soil water content was estimated using a neutron probe. Soil cores were taken to quantify the amount and distribution of roots. Plant phenology, dry weight of plant parts, and yield were measured as a function of time and treatment. Irrigation increased leaf area, crop growth rate, biomass and yield, and delayed reproductive development. Early in the season, the 20-cm irrigated treatment had a higher soil water extraction than wide rows but later in the season the difference was smaller. Water use efficiency was least in 20-cm rows. Light interception was greater at narrow row spacings (20 and 35 cm) than wide row spacings during most of the growing season. Narrow rows (20 and 35 cm) gave the highest yield.

P 2.17 - The effects of irrigation levels and nitrogen fertilizer for drought damages decrease on yield and yield components of sunflower

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Sunflower (Helianthus annuus L.) is an annual plant with oil enriched seeds. It is very important to study the methods to increase its yield and to use maximum possible environmental conditions. One of these methods is to determine the best irrigation for drought effects and nitrogen fertilizer level for this crop. To do so, an experiment was performed using a randomized complete block design with a split-plot layout and four replicates. The main plots were four irrigation levels (ratio of irrigation water to evaporation from class A pan, IW/EP, of 0.45, 0.55, 0.65 and 0.75). The sub-plots were 0, 50, 100 and 150 kg/ha of top-dressed nitrogen fertilizer which were applied when the plants had 12 leaves. The results of this study showed the minimum and maximum yield of 5,066 and 6,380 kg/ha were obtained with IW/EP of 0.45 and 0.65, respectively. Grain yields of 100 and 150 kg/ha N levels were equal statistically and they were greater than zero and 50 kg/ha N treatments. Increasing irrigation water up to IW/EP of 0.65 increased grain yield and had no significant effect after this level. Increasing this ratio to 0.75 decreased the water use efficiency. Water use efficiency of IW/EP = 0.65 was 1.18 kg/m and that of IW/EP = 0.75 was 0.98 kg grain per m of water. The positive relation between CGR at the time of antithesis and grain yield showed that it is possible to estimate yield if CGR is calculated. Generally, it was found that using IW/EP = 0.65 with drought effects decrease, and applying 100 kg/ha top-dressed N fertilizer; the grain yield of sunflower may be more than 4,500 kg/ha.
**P 2.18 - Effect of water deficit and potassium on yield architecture of soybean (Glycine max L. Merr.)**

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Drought is an environmental factor that influences soybean yield. Potassium availability in soil can reduce drought damage in plants. The objective of this study was to evaluate the effect of water deficit and potassium on architecture of soybean yield. Three levels of water deficit including irrigating when soil water content got 60, 40 and 20% available water as main plot and three levels of potassium applying including 0.5 and 10 gm\(-2\) K\(_2\)O as subplot were conducted in a split plot design based on RCBD on farm conditions. The results showed that yield decreased when stress occurred on soybean. The most seed and pod number set on main stem in all of treatments, but water deficit significantly reduced them. Improving stress intensity declined seed to pod weight ratio in plant. Stress caused plants to abort flowers and pods. The ratio of seed and pod numbers in main stem to total seed and pod number were the highest when stress intensity was increased. Seed and pod weight in main stem to seed and pod weight in plant ratio declined when plants were grown in well-watered conditions. Applying potassium increased pod number and weight on main stem nodes. When 10 gm\(-2\) was applied, seed and pod number were increased on all fertile nodes on main stems. Potassium was more effective when stress intensity was more. Applying 5 gm\(-2\) potassium made seed and pod number, and weight in intermediate nodes on main stems increase. When 10 gm\(-2\) potassium was applied, seed and pod number, and weight were increased in all of the nodes. However, the upper and lower nodes were influenced more.

**P 2.19 - Vegetation indices to predict plant water stress**

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Availability of water is one of the most limiting factors in crop production. Current technologies for measuring plant water status are limited. Considering plant and irrigation management it is essential to discriminate between water stress and various other possible abiotic stress factors. A field study was conducted to determine specific reflectance wavelength ranges responsive to water and nitrogen stress in durum wheat. Plot experiments were carried out at Foggia (southern Italy) on a clay loam soil. Reflectance of wheat plants grown under drought and well-irrigated conditions and under nitrogen deficiency was measured. Spectral vegetation indices (VIs) were measured with a FieldSpec spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA) at the booting stage of wheat plants. Leaf RWC (%) was calculated to quantify crop water status, and N leaf content was used to determine crop N status. Analysis of this data indicated that it is possible to use remotely sensed data to develop maps of water stress and N status when variations in all of these factors are simultaneously present.
P 2.20 - Growth analysis of advanced rapeseed cultivars under desirable and deficient irrigation

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In order to investigate the effect of cutting off irrigation on physiological indices in rapeseed (Brassica napus L.) cultivars, a field experiment was conducted as split-plot arranged in a Randomized Complete Block Design (RCBD) with four replications in 2002/03 in Karaj, Iran (at: 35°59 northern and 50°75 eastern). There were two factors: Irrigation at two levels (80% of evaporation as desirable, and cutting off irrigation started from stem elongation stage) as main plots. Cultivars were: Sarigol, Goliath, Heros, Comet, Amica, Sw5001, Crackerjack, Eagle, Wildcat, Swhotshot as sub-factors. Result showed that maximum Total Dry Matter (TDM) in all of the cultivars happened in 2303 GDD that Comet c.v. (in desirable) and Crackerjack c.v. (in cutting off irrigation) had maximum and minimum TDM, respectively. Leaf Area Index (LAI) up to 995 GDD was little but with passing of time, from 1421.5 to 1649.5 GDD maximum LAI happened and then gradually decreased. The major increase in Crop Growth Rate (CGR) was due to increase of LAI. Heros and Wildcat c.v. under deficient irrigation had more and less CGR, respectively. However, Heros & Comet c.v. due to more LAI and CGR had the best grain yield under deficient irrigation compared to other cultivars.

P 2.21 - Genetic control of water use efficiency in Brassica and Arabidopsis

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Water use efficiency (WUE) is a complex quantitative genetic trait with a strong environmental interaction. Identification of genetic loci that control WUE, and understanding the environmental conditions where specific loci become important is challenging, but will be key to successfully applying marker-assisted selection approaches for improving WUE in a range of environments. Advanced genetic and genomic resources in both Brassica oleracea and Arabidopsis thaliana offer a powerful comparative system in closely related crops and model plant species to investigate the genetic control of WUE. QTL for gas-exchange, carbon isotope discrimination (Δ13C) and stomatal densities have been established in a mapping population of Brassica oleracea under non-stressed glasshouse conditions, and QTL for Δ13C determined in the field [a]. We have determined relationships between Δ13C, Δ18O and yield response to irrigation for Brassica oleracea on two contrasting field sites and will describe our progress in seeking additional QTL for yield response, Δ13C, Δ18O and gas-exchange parameters using a second doubled haploid Brassica oleracea mapping population and associated substitution lines on the two field sites. Our recent work towards identifying genetic diversity and QTL for WUE in Arabidopsis thaliana will be described, and this information will be both integrated with Brassica oleracea QTL and recently published Arabidopsis thaliana Δ13C QTL[b].

P 2.22 - Modelling the interaction genotype x environment to predict crops’ response

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In Sahel, scarcity and randomness of water resources are the main explanation of the variability of the plant response in multilocation trials. This variability is known for plant breeders under the name of interaction between genotype and environment (G x E). To choose a genotype for a given environment supposes to be able to predict what each genotype will produce under a range of predictable agroclimatic situations of this environment. Most of the classical G x E interaction analysis methods describe the phenotype by a function of the genotype and environment effects that can be estimated from agronomic trials. However environment is variable from year to year and this approach cannot result in good prediction of genotypes performances in a new environment. Nevertheless, factors that must be taken into account are known for a given environment. They include for each trial, rainfall, solar radiation, wind, etc. The problem is that these climatic variables are too many. Water balance models exist and make it possible to take into account the climate effects on cultures, but their parameters must be determined for each new genotype, which is expensive. We propose to predict genotypes’ response in new environments taking into account their climate, without excessive costs. The tool to be developed is intended initially for Sahel plant breeders who will be able, in short plant breeding programs (2-3 years), to reduce the uncertainty of the new genotypes performances prediction.

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P 2.23 - Effect of grapevine deficit irrigation and soil management on canopy microclimate, fruit quality and yield

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The main objectives of this work are to contribute to the development of strategic water management for drought alleviation and sustainable agriculture and to investigate a range of technologies for soil and crop management. This research was conducted during the 2004 growing season (May-September) in a commercial vineyard at the “Six Kings” company, southern Portugal (170 km southeast of Lisbon). This paper describes the results of the first year of application of different irrigation treatments (DI-deficit irrigation; RDI-regulated deficit irrigation; PRD-partial root drying) to Aragonez (syn. Tempranillo) grapevines. A comparison of soil tillage (ST) with natural cover (NC) was also undertaken. The responses of vines to soil water availability were evaluated by leaf gas exchanges, water relations, plant vigour; canopy microclimate, berry composition and yield. The predawn water potential (\(\Psi_{pd}\)) was significantly lower in the NC treatment compared to the ST. RDI grapevines presented a higher water status during the beginning of berry growth and lower during the ripening period (August) comparatively to the other treatments. During most of the ripening period \(\Psi_{pd}\) of PRD grapevines were higher than those of DI ones, which can be attributed to the lower vegetative growth and also to the reduced stomatal conductance (\(g_s\)) observed in this period in PRD vines. Yield and fruit quality did not differ significantly between the three irrigation treatments as well as between the two soil management practices.
P 2.24 - An innovative approach for effective utilization of water and soil in drought-prone areas

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Cocopeat or coir dust is a by-product of the coir industry from coconut husk, often kept unutilized or burnt down. Due to environmental concerns and also diminishing supplies of peat soils for horticultural substrates, cocopeat is being considered as a renewable peat substitute. However, in its raw form, cocopeat has been reported to contain phytotoxic elements, which inhibit plant growth. The present study was conducted to check the effect of processed cocopeat on plant growth parameters. Raw cocopeat contains a greater amount of soluble salts (E.C. value > 1.0), high C/N ratio and deficient nitrogen. To overcome the above said problems, raw cocopeat is washed with good quality water until the E.C. level reduced to 0.4, mixing cocopeat with nitrogen (0.75%) alleviates nitrogen deficiency problem and lower C/N ratio. An experiment was designed, chilly seeds were sown both in the vermicompost blended processed cocopeat and vermicompost blended raw cocopeat without any field preparation. The processed cocopeat absorbs and retains a greater amount of water (1 liter of cocopeat absorbs 70 liters of water) and releases the water as and when the crop requires, evaporation loss is very minimum, increases water percolation and water holding capacity of the soil, and also it gives better support to the growth of the plant when mixed along with vermicompost. The number of irrigation requirements are less when compared to regular cropping practices (the replacement of flood irrigation once in ten days, by sprinkler irrigation once in three weeks yielded good results). The seedling grown in an untreated cocopeat showed nitrogen deficiency symptoms and also the mortality rate was high because due to presence of high soluble salts. The plants on “processed” cocopeat produced higher root dry weights (24%), fruit numbers (48%) and total yield (68%) when compared to regular cultivation. Effective cost of production is ensured.

P 2.25 - Soil and water exploitation for maximizing productivity of tomato-faba bean under stress ecological conditions

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The optimistic Toshky National Project represents a strong challenge to cultivate new reclaimed lands under stress ecological conditions. The aim of this research is to compare competition between natural rock phosphate (NP) and super phosphate (SP) fertilizers on a single crop, as well as intercropping tomato with faba bean for utilizing land equivalent per water unit. A field experiment was carried out for two years during the 2001-2002 and 2002-2003 seasons, at the South Valley Agriculture Research Station, Toshky. The treatments included phosphate sources (natural rock phosphate and super phosphate) as well as doses. Transplanting dates for tomato hybrid (castle rock) were on 1st and 7th September in the 2001-2002 and 2002-2003 seasons, respectively. Sowing dates of faba bean were 15th and 22nd October in these two seasons, respectively. Drip irrigation was used. Tomato seedlings were transplanted on one side for each lateral 50 cm between drippers. Faba bean seeds were planted in hills spaced 10 cm between hills, one plant per hill. Yield and yield components of faba bean were decreased by intercropping faba bean with tomato compared with faba bean grown alone, in both seasons. The response of seed yield and yield components to phosphate levels was linear; between zero and 60 kg P2O5/acre. Intercropping tomato with faba bean compared with tomato grown separately in both seasons decreased tomato fruits yield and marketable fruits yield. Results indicated that in all studied tomato characters improved with increasing phosphate fertilizer, except culls percentage which decreased with increasing phosphate fertilizer compared to control in both seasons. Total yield and marketable yield increased with increasing mixed phosphate compare to control in both seasons. The highest value for Land Equivalent Ratio was 1.91 and 1.99 for the treatment using mixed phosphate in the first and second seasons, respectively. Intercropping tomato with faba bean has maximized utility of irrigation water by saving 31% compared to separate treatments.
P 2.26 - Productivity and water relations of corn plants grown under different conditions of water supply and potash fertilization

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Two field experiments were conducted in Shalakan, Egypt, during 2000 and 2001 seasons, to study the effect of some levels of irrigation (I) and potassium (K) on corn (S.C.10). Such two factors were arranged in a split plot design with four replicates, where irrigation levels were run at the main plots, while the sub ones were devoted to potassium levels. Four irrigation treatments, i.e. 80, 60, 40 and 20% of available soil moisture (ASM) were tested. Potassium levels were 57, 86, 115, 144 kg K₂O/ha. The study included 16 traits in addition to some water relationships. The obtained data showed that irrigation gradually increased products of most traits, including grain yield. No. of rows/ear did not response to irrigation varying, meanwhile shelling % increased as irrigation level was reduced. Potassium addition up to 86 kg/ha reflected in positive effect on most studied aspects, including grain yield. The relation between either (I) or (K) levels and grain yield/plant was quadratic. The interaction showed insignificant effect on most studied traits. It was concluded that 80% ASM in combination with 57 or 86 kg K₂O/ha produced the highest grain yields water consumptive use (WCU) increased by increasing irrigation and through hot seasons. The value of (WCU) was ranged between 3663 to 6123 m³/ha. The treatments 80% ASM, 57 kg K₂O/ha and their combination produced the highest values of water use efficiency (WUE) in both seasons.

P 2.27 - Post-harvest quality of pear fruits from irrigated and non-irrigated orchards

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Although the effect of water stress on crop production has been extensively studied, its impact in the post-harvest quality of products is largely unknown. Therefore, in the present work we studied the post-harvesting characteristics of pear variety “Rocha” produced in central Portugal, in irrigated (Ir) and non-irrigated (NIr) orchards. After harvesting the fruits were stored at 0 ºC. The in vivo values of the minimal (F₀) and the maximal (Fm) fluorescence of chlorophyll a (Chl a) and of the maximal photochemical efficiency of PSII (Fᵢ/Fm) were determined in the fruits' epidermis by modulated fluorometry. Peel's total chlorophyll (Chl a + β) and carotenoids content was measured as well as the pulp firmness and the total content of soluble solids. During cold storage all measured fluorescence parameters decreased in both irrigation treatments. Nevertheless, F₀ and Fₘ were higher in the NIr fruits. F₀ decreased more steeply in Ir fruits. Also, Fᵢ/Fₘ decreased during storage, but it seems not to be affected by the irrigation treatment. At harvest, Ir and NIr fruits had similar firmness but after 4 months of cold storage, NIr fruits seemed firmer than Ir fruits. Total soluble solids were apparently not affected by storage. Total chlorophyll content was lower in Ir fruits, but it decreased in a parallel way in both groups during storage. The total carotenoids content increased slightly in the NIr but not in the Ir fruits. The ratio Chl a + β Carotenoids decreased in both groups. Under storage the NIr performed better than the Ir fruits.
P 2.28 - Response of agronomic crops to use of deficit irrigation in the Thrakya Region, Turkey

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The yield response to deficit irrigation of different crops is major importance in production planning where water resource is limited as Trakya Region in Turkey. This study was conducted to determine water-use characteristics of agronomics crops; wheat, sunflower, watermelon and bean under deficit irrigation management in the Trakya Region. The seasonal evapotranspiration, water-use efficiency, yield response factor and yield were determined under the condition of which 0, 25, 50, 75 and 100% of water requirement was applied during the whole growing season for all crops. The seasonal evapotranspiration (ET) and yield of all crops were the highest in the control treatment which was designated to apply 100% water requirement and the lowest in the non-irrigation treatment. The yield response factor (ky) which relates relative yield decrease to relative evapotranspiration deficit were found to be 0.74, 0.85, 1.27, 1.04 for wheat, sunflower, watermelon and bean, respectively. Based on the these results, when such crops are grown within the same project area and maximum production per unit volume of water be aimed at watermelon and bean would have the priority for water supply.

P 2.29 - Drought: risks in Brazilian soybean producing regions

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Water availability fluctuation is the main factor responsible for soybean yield variability in time and space in Brazil, and is the main limiting factor in obtaining near potential yields. Increments in yield and reductions in crop costs and risks became basic requirements for competitiveness in the current modern agribusiness world. Tools to help the decision making process are essential to tackle these challenges and to obtain competitive and environmentally sustainable products. A collaborative project involving several Brazilian institutions (MAPA, EMBRAPA, ANEEL, INMET, IAPAR) was developed to demarcate areas with lower risks for soybean cropping in the states of PR, GO, TO, MS, MT, MG and BA. Areas with different probabilities of water deficit occurrence during the most critical phase of the crop development were characterized as favorable, intermediate and unfavorable, using soybean crop water balance models, geographical information systems and geostatistics. Different sowing dates, water availability in each region, water consumption in the different stages of development of the crop, soil type and cultivar were considered. For each State, 54 to 72 maps were generated as a result of the combination of nine or 12 sowing dates, three soil types and two cultivars. Each map portrayed a combination of a level of each one of the factors listed above, representing the drought risk classification of different areas of the State for a given sowing date as a function of the soil type and cultivar. These results are presently used by Brazilian governmental policy makers for financing and insure agricultural activities.
P 2.30 - Yield and quality of durum wheat as affected by foliar glycinebetaine applications in rainfed Mediterranean conditions

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Durum wheat quality is closely connected with nitrogen fertilization. To minimize yield reduction due to water stress during grain filling and ripening stages in semi-arid environments of Mediterranean areas, farmers typically apply nitrogen fertilizer at lower rates than are required for optimum performance of durum wheat. An increase in water stress tolerance through foliar application of compatible osmolytes could allow more efficient utilization of higher nitrogen rates, thus, improving grain quality and its stability over years. This research evaluated the effects of different rates and timings (according to growth stage) of foliar applications of Glycinebetaine (a natural osmoprotector) on yield and other commercial and qualitative parameters of durum wheat. The experiment was carried out during 2001-2003, at the Sparacia experimental farm (AG, 37°37' N - 13° 42' E), in a characteristic area for the cultivation of durum wheat. The experimental design was a split-plot with three replications. Two nitrogen rates (N60, N120) were combined with six Glycinebetaine (GB) treatments (D1-T1, D1-T2, D2-T1, D2-T2, Split, D0) in a factorial arrangement. “D1” and “D2” were 1 kg ha⁻¹ and 2 kg ha⁻¹ GB, respectively. “T1” was the GB application at the stem elongation stage, “T2” was the application at the booting stage of durum wheat. The “split” treatment was the application of GB at 1.5 kg ha⁻¹ at “T1” plus 1.5 kg ha⁻¹ at “T2”; the “D0” was the non-treated control. During the experiment, the pluviometric trend was highly variable. The first year of the experiment was very dry (320 mm) and the repeated water stresses during the grain development stages caused yields decrease. However, the GB treatment showed favourable effects on yield and commercial grain characteristics (less kernels shriveling), especially when applied as a “split” with higher nitrogen rates (N120). During the second year, the pluviometric trend was more favourable (617 mm) and representative of the poly-annual means. The GB treatment showed a significant effect on the yield, with the minimum rate “D1” achieving the maximum efficiency when “T2” treatment combined with the maximum nitrogen rate (N120) was applied. Besides the GB treatment, in every application in combination with “N120”, the protein and gluten grain content increased; thus it appears that the grain sinks increased in capacity to accumulate nitrogen protein. That was further suggested by higher level of non-vitreous kernels in the combinations with GB-N60. In this treatment, the predisposition to accumulate more nitrogen was not satisfied by a proportionate nitrogen fertilization rate, consequently, an increase in starchy kernels phenomena due to nitrogen deficiency appeared.

P 2.31 - Influence of water deficit on durum wheat grain protein composition and technological quality

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Water deficit is one of the major environmental factors affecting durum wheat grain quality under Mediterranean climate. While many studies have been carried out on the effect of high temperature on wheat dough properties, the effect of water stress wasn’t investigated as extensively. So the aim of this study was to evaluate the influence of water regime on grain protein composition of durum wheat in relation to technological quality. For this purpose, in three cropping seasons, two cultivars (Simeto and Ofanto) were grown in field under two water regimes (irrigated and rainfed) in Foggia (Southern Italy). On grain samples taken at harvesting, the following quality analyses were performed: protein and gluten content, gluten index and SDS test. Furthermore, the following protein fractions were evaluated: gliadins, glutenins, HMW-GS, LMW-GS and unextractable polymer proteins (UPP). An improvement of technological quality was observed under water deficit consistent with an increase in glutenin, HMW-GS/LMW-GS ratio and UPP. Principal component analysis performed on the correlation matrix of the different variables, allowed two factors to be identified explaining 72.9% of the total variance. A sharp separation between the two cultivars was clearly evident on factor 1, linked to technological indices and glutenin content, with Simeto showing the best performance. On the other hand, the effect of water regime was mainly evident on factor 2, linked to protein and gluten content, in the first two cropping seasons and on the first factor in the last cropping season, when drought occurred during grain filling.
Irrigating sugar beet (Beta vulgaris L.) by means of a decision support system in Italy

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The research on irrigation volumes and systems to enhance yield and financial return of the sugar beet crop, is one of the major tasks Beta is involved in. In this frame, AcquaFacile (literary “EasyWater”), a DSS irrigation software (downloadable from www.betaitalia.it) has been developed. Its water balance is based on the Hargreaves’s equation (Hargreaves et al. 1982), with reduced crop coefficients with respect to the common references (FAO 1979 and 1998). It also takes into account the contribution from the shallow water table. In 2004, two types of plot trials were carried out on spring beets: in the first one (four sites), a rainfed treatment was compared with a 50% restoration of AcquaFacile-calculated water deficit (50% AF), with a 100% restoration (100% AF) and with a 100% tensiometric control. In the second type (three sites), a financial comparison was carried out among dripping tape, fixed mini-sprinklers, travelling gun and boom at 100% AF, plus a rainfed control. The different yield potential and precipitation among sites have brought about a wide range of responses to irrigation, in terms of both root yield and sugar content. Of particular significance, root yield was always observed, while sugar content showed a short decrease in two locations, a short increase in one location and a significant loss in the site with the lowest precipitation. The average seasonal water deficit was 191 mm. At harvest, two points may be highlighted: irrigation has always increased the crop yield and financial return; 100% AF proved the optimal irrigation volume and the software validity, with increases in financial income almost double than 50% AF. At the same time, the two travelling systems were more profitable than the two fixed ones, due to comparable yields but lower fixed costs.

Deficit irrigation may not increase net benefits if uncertainty is ignored!

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Deficit irrigation has been touted as a strategy to increase overall system benefits. However, ignoring the inherent uncertainty in crop water demand has been the common practice which we show as undesirable. To deal with the problem of uncertainty, a constraint state formulation for stochastic optimization of the weekly deficit irrigation strategy is developed. This formulation is based on the first and second moment analysis of the stochastic soil moisture state variable, considering soil moisture at both saturation and deficit cases as the maximum and minimum bounds, respectively. The results of the optimization model is compared with those obtained using the simulation model. As a result, an optimal deficit irrigation scheduling is determined based on this explicit stochastic optimization model. Also, the optimization and simulation results showed the importance of considering crop water demand uncertainty to determine the optimal deficit irrigation strategy. The results indicates that achieving a high long-term expected relative net benefit by decreasing the crop water allocation and increasing the irrigated land may fail as a strategy when crop demand uncertainty is ignored the during the optimization process. Moreover, the proposed methodology is a continuous variable stochastic modeling avoiding discretization of state variables thus avoiding the well-known ‘curse of dimensionality’.
P 2.34 - Mapping of drought impact on olive growing in Tunisia

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During the 1999–2002 period, olive growing in Tunisia had faced a very hard drought. The rainfall deficit reached in some regions more than 50% of normal amount. Under these conditions, several olive trees’ behaviours were observed. To characterize these reactions, an affection scale was established. This scale has three levels which are: 1-normal state, 2-growth stop without withering and 3-withering or fading. Using this scale and field investigations, the map of olive trees’ reaction to dryness was drawn for all of Tunisian olive groves. Under the same severe climatic conditions, several olive plants’ reactions were observed in the same region. This phenomenon suggested that other factors influenced plant behaviour. Indeed, the regional maps of severity and rainfall deficit did not shown a good overlap. Many other parameters in relation with the zones and the plantation characteristics were studied. The results show that, there is a good superposition between olive reaction and plantation ages maps. Thus, under the same drought conditions, the senescent orchards are less resistant. On the other hand, the influence of soil type was identified. In fact, the worst soil type for olive growing under dryness conditions is gypseous one. The silty and clay soils are also unfavourable for olive growing in drylands. However, fine elements content of about 20% is positive to this growing. On the other hand, sandy soil seems to be the best under these conditions.

P 2.35 - Similarities in peaks of sun-spot numbers, years of drought and annual plant biomass in the Kara-Kum desert of Turkmenistan

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The 11-year cycle of peaks of annual sun-spot numbers may influence the atmosphere and biosphere. In the large flat areas of central Kara-Kum Desert of Turkmenistan, such as near Erbent, Daraly and Chshme, a significant correlation was found during 36 years, between peaks of sun-spot numbers, the rainfall amounts, the numbers of days with water available to plants in the upper layers of the soil and the peaks of annual amount of plant biomass produced ($R^2 = 0.94$). In the years when there are more sun-spots, the amount of rain and plant biomass is greater. The annual rainfall in this region is between 50 and 200 mm in spring, when temperatures range between 5 and 20 °C. In summer the temperatures can reach 75 °C and very low R. H. This region has a relatively cool winter with temperatures from -10 to -2 °C, and small amounts of snow. The vegetation consists mainly of annual plants but includes some perennials such as Poa bulbosa, Carex physodes, and some Astragalus and Artemisia species. Mathematical and empirical models have been developed in order to be able to predict plant biomass productivity in the central Kara-Kum Desert. Despite large fluctuations of rainfall, a prediction of plant biomass in a given year is possible, and is very important for inhabitants of those desert areas, who are breeders of sheep, goats and camels. In locations close to a sea or high mountains or irrigated large areas, this effect diminishes.
P 2.36 - Performance of almond and pistachio trees in dryland areas of Tunisia

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In dryland areas of Tunisia the water availability to arboriculture is limited. However, the increase of water use efficiency can be realised through the improvement of dry matter accumulation by trees. Many research has been developed on nut trees species presenting adaptive mechanisms to drought. Almond and pistachio trees were considered as very drought tolerant crops. The ability to endure high water deficits was related to efficiency in valorising marginal soils under high evaporative demand and chronic shortages of water. In the arid regions of Tunisia, severe drought to the point of threatening the survival of the trees is frequent. The productivity of almond and pistachio trees were investigated under limited water supply conditions. The yield of different cultivars was determined for several years as well as climatic data of the orchards. Important yearly fluctuations in rainfall and temperature were observed. The result revealed a close relationship between those factors and yield. In fact, a correlation was found between seasonal rainfall and yield. This phenomenon seems to be an important physiological adaptation of almond and pistachio growing in arid zones improving water use efficiency.

P 2.37 - Effects of drought levels and planting date on phenology, physiological characteristics, yield and yield components of three chickpea (Cicer aritinum L.) cultivars

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In order to investigate the effects of different drought levels and planting date on phenology, physiological characteristics and yield and yield components of chickpea cultivars, a two-year experiment was conducted during the 2002 and 2003 growing seasons in Mashhad, Iran. Four drought levels including I1 = no irrigation, I2 = irrigation only at planting time, I3 = I2 + irrigation at before flowering; and I4 = I3 + irrigation at pudding were performed. Three Kabuli chickpea cultivars (Jam, Karag 12-60-31, and ILC482) in planting date (Jan 20 and Mar 5) were compared in a factorial experiment based on randomized complete block design with three replications. Significant difference among number of branches, number of pods and number of seeds m-2 in all treatments were observed. Karag 12-60-31 cultivar, at first planting date and I4 had the highest seed yield while at second planting date and I4 had the highest seed yield. However, at second planting date and I1, ILC 482 cultivar had the lowest. I4 at the early flowering had the highest dry matter (5.55 and 42.22 g m⁻² in two year, respectively) while at I1 had the lowest (40.21 and 36.92 g m⁻² in two years, respectively). I4 at the early flowering had the highest leaf area index (3.10 and 2.40 in two years, respectively) while I1 had the lowest (2.02 at first year and 1.60 at second year). The highest dry matter and leaf area index was obtained in I4 at the early flowering while the lowest was observed in I1. However, it was an interaction between cultivars and irrigation regimes both for dry matter and LAI. At first planting showed better dry mater (51.40 g m⁻²) and leaf area index (2.55) compared to second planting date (30.93 and 1.69 g m⁻²). Karag 12-60-31 in I4 had longer growth period compared with others cultivars. Jam cultivar was the most stress tolerant among the studied cultivars. Karag 12-60-31 cultivar showed the highest performance under full irrigation and had more seed yield.
P 2.38 - Effects of irrigation regimes on phenology, physiological characteristics, yield and yield components of wheat (Triticum aestivum L.) cultivars

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In order to investigate the effects of different irrigation regimes on phenology, physiological characteristics, yield and yield components of wheat cultivars, a two-year experiment was conducted during the 2000-1 and 2001-2 growing seasons in Mashhad, Iran. Four irrigation regimes including I1 = no irrigation I2 = irrigation only at planting, I3 = I2 + irrigation before flowering, I4 = I3 + irrigation at shutting and I5 = I4 + irrigation at seeding and four wheat cultivars (Sabalan, Sardary, AzarII and Chamran) were compared in a factorial experimental based on randomized complete block design with three replications. Significant different was observed in number of spikes m⁻², number of grains per spike and 1000-seed weight between irrigation regimes. The highest number of spike m⁻² (763.75 and 520.83 in two years, respectively) number of grains per spike (33.83 and 31.60 in two years, respectively) and 1000-seed weight (43.29 and 49.10 g in two years, respectively) and seed yield (3533.83 and 3797.80 kg ha⁻¹ in two years, respectively) were obtained in I5 irrigation. Interaction between irrigation regimes and cultivars showed that the highest number of spike m⁻² (803.33 and 545.00 in two years, respectively), number of grains per spike (36.66 and 37.90 in two years, respectively) and 1000-seed weight (48.66 and 44.00 g in two years, respectively) and seed yield (3763.66 and 4395.70 kg ha⁻¹ in two years, respectively) were obtained in I5 and Chamran cultivar while Sabalan cultivar in I1 had lowest. The highest dry matter and leaf area index was obtained in I5 at the early flowering while the lowest was observed in I1. However, it was an interaction between cultivars and irrigation regimes both for dry matter and LAI. Chamran cultivar in I5 had longer growth period compared to others cultivars. While Chamran cultivar showed the highest performance under full irrigation, Sardary was the most stress tolerant among the studied cultivars.

P 2.39 - Participatory technology selection for improving rainfed rice production

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Adoption of management technologies is limited in rainfed ecosystems due to several reasons. Poor popularization and dissemination of the technologies is one such missing link. Participatory technology selection (PTS) is a promising approach to disseminate viable technologies among rainfed farmers who are basically risk avoiders. Potassium is an essential nutrient for plant growth and development. Uptake of potassium is primarily by diffusion through roots and low soil moisture under drought stress may limit its uptake (Sordi and Fulop, 1994). Under such situations, an additional supply of potassium either through seeds, soil and foliage may be effective to sustain growth and development. Different methods of potassium application viz., T1: seed treatment with 1% KCl, T2: 1% KCl foliar spray, T3: 25% additional potassium through soil and their varied combinations were evaluated using PMK3 rice cultivar under rainfed conditions. There was a total rainfall of 569 mm during the cropping period and out of which only 42 mm was recorded during post flowering phase with a dry spell of 15 days. At this stage, farmers were asked to evaluate and score different treatments for number of tillers per plant, panicle length, drought score, grain and straw yields. PTS indicated the positive impact of potassium application through seed treatment, 25% additional soil application and 1% KCl foliar spray over control and other treatments by recording highest yield of 3.8 t/ ha. PTS was found to be useful in disseminating the management technologies among rainfed rice farmers.
P 2.40 - Canopy nitrogen distribution and photosynthesis during grain filling in irrigated and water stressed sunflower genotypes

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The objective of this research was to estimate canopy photosynthesis of sunflower genotypes during grain filling when subjected or not to a severe water stress period during the leaf expansion period. In 2004, four sunflower genotypes with contrasting leaf area profiles were grown in Toulouse (SW France) under a mobile rain shelter and were subjected to two water treatments: (a) well-watered conditions; (b) continuous 30-day-drought period, ending at anthesis, then full irrigation. The study was made in two steps: an experimental quantification of leaf area profile and vertical leaf nitrogen distribution, an estimation of the light extinction profile using an architectural modelling method. Comparisons were made between simulated and observed values of canopy photosynthesis. Significant differences were observed between irrigated and water stressed plants for leaf area, vertical leaf N distribution and light extinction profiles. Moreover, genotypic differences for the response of these traits to water stress were observed. This should result in significant genotype x environment interactions when using these genotypes under contrasting water regimes.

P 2.41 - Effects of seeding rate and genotype on seedling establishment and grain yield of direct seeded rainfed lowland rice (Oryza sativa L.) with different water availability in northeast Thailand

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In northeast Thailand, direct seeded rice is increasing instead of transplanting, but seedling establishment is sometimes poor and not optimized. Seedling establishment and grain yield of 3 seeding rates (31, 63, 125 kg ha⁻¹) and 14 genotypes were compared in toposequentially lower (favourable water) and upper (drought around flowering) fields in 2003 and effects of water-limitation during seedling establishment in 2004 in Ubon Ratchathani, Thailand. In 2003, higher seeding rate resulted in a higher plant number per m² and larger panicle number in both lower and upper fields. However, seeding rate didn't affect grain yield in either of the fields because spikelet number per panicle was lower with higher seeding rates. Genotypes with higher numbers of seedlings achieved larger panicle numbers except for two genotypes in the lower field. However, there was no relationship between number of seedlings and panicle number among genotypes in the upper field because fertile panicle numbers of late maturing genotypes decreased due to late season drought. Both in lower and upper fields, genotypes with larger panicle numbers tended to achieve higher grain yield. In 2004, 6 and 15% of sown seeds did not mature (i.e. failures of establishment) under favourable and water-limiting conditions, respectively, and panicle number was smaller under water-limiting conditions. Plant length was greatly suppressed and panicle weight was lower under water-limiting conditions. This study suggests improved seedling establishment should be combined with improved yield formation, and mechanisms of poor seedling establishment should be further investigated under various environmental stress conditions.
P 2.42 - Evaluation of drought tolerance in wheat genotypes by drought indices

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Water deficit is an important yield-decreasing factor in wheat genotypes. In order to compare responses of wheat genotypes to water stress and selecting suitable genotypes for arid and semi-arid zones and finding the best drought tolerance indices, an experiment was carried out. Twenty-two wheat genotypes were planted in two separate experiments, one with normal irrigation and another with dry-farming condition using RCBD with three replicates, and three planting dates (10 October, 10 November, and 10 December). Combined analysis showed that there was a significant difference in both conditions, planting dates and genotypes in all traits. The results showed that water stress decreased grain yield, plant height and harvest index. Normal irrigation condition increased grain yield 1.4 ton/ha more than dry-farming condition. Late planting dates decreased grain yield 715 kg/ha, plant height 17.8 cm, and 1,000 kernel weight 9.5 g. SXL/GLENSON, CSM*3/3, 1-32-1317/... and P8-5/KAVKAZ showed highest yield. These genotypes had the highest harvest index, number and weight of spike/m², spike length and number of total and matured tillers. Stress tolerance index, geometrical mean, relative water content and cell membrane stability showed that SXL/GLENSON, CSM*3/3, 1-32-1317/... and P8-5/KAVKAZ had high tolerance to water stress. These genotypes showed high yield in stressed and non-stressed conditions. Path analyses showed that harvest index, number of total tillers and number of spike/m² had a positive effect on grain yield in non-stressed and stressed conditions. Due to the grain yield results, it seems that stress tolerance index (STI) and geometrical mean (GMP) are the best indices for the evaluation of drought tolerance.

P 2.43 - Drought stress effects on biomass production and some qualitative traits of forage sorghum

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Sorghum [Sorghum bicolor (L.) Moench] is an important forage crop in semiarid and arid regions of the world. One of the major challenges for sorghum improvement programs is to develop plants that have an advantage in water limited environments. Two field experiments were conducted in semiarid environments of Iran in 2004 on a clay loam soil to investigate the effects of water stress on biomass production and some qualitative traits of sorghum cv. Speed feed cultivated for hay, the only dominant cultivated hybrid cultivar in Iran. Four irrigation treatments were used at about 7-, 14-, 21-, and 28-day intervals from sowing till the harvest in a randomized complete block design with four replicates. In both experiments, a significant reduction was observed for plant height and number of leaves/plant with increments in irrigation intervals. A significant increase was observed in crude protein percentage, cyanidric acid and tannin contents by an increase in drought intensity, which caused tannin to reach to a toxic level at 28-day irrigation intervals. But total above ground dry biomass did not increase significantly in drought treatments in comparison with that of controls. Taken together, the results imply that total above ground dry biomass was not affected by drought but forage quality decreased in drought conditions.
Improving wheat yield and sustainability in warmer areas through permanent raised bed: save water and reduce environmental pollution

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The combined effects of tillage options, nitrogen management and levels on wheat (*Triticum aestivum* L.) as a winter crop on raised beds has increased productivity in the temperate world but has not been investigated in multi-cropping systems such as rice-wheat in Bangladesh. Therefore, a study was conducted during 3 wheat seasons at the Wheat Research Center experimental field in Rajshahi (NW Bangladesh), to compare the effects of tillage options, nitrogen levels and management strategies on wheat. In a strip-split plot design, two tillage systems were tested: manually prepared, permanent bed (PB—as this is in reference to 2 other crops besides wheat per season sown on the same beds) and conventionally tilled on the flat (CTF). Within the each tillage system, two nitrogen management practices were used: broadcast, (BC) and furrow placement (FP) between wheat rows. Three N levels of 50, 100 and 150% N ha⁻¹ of recommended N (representing 60, 120 and 180 kg ha⁻¹) were used. Wheat yields predictably responded to N fertilizer rates in all years over all treatments. There were no statistical differences between the two nitrogen management, i.e. BC and FP in 2 out of 3 years. Using raised beds at 150% N rate was statistically higher in all years. Using raised beds at 50% N rate was statistically equal to 150% conventionally tilled in all years. The data indicate that by using raised beds compared to conventional tillage, nitrogen uptake and efficiency can be increased. The maximum N uptake by the grain and total N uptake by the plant was recorded in PB where the highest dose of N was applied. Permanent bed tillage systems also showed substantial water saving (25%) over the CTF treatments. Thus, in warmer areas with multi-crop systems where water resources are often limited and nutrient uptake and efficiencies are low, the use of raised beds in a permanent bed cropping system would be a distinct advantage.
P 2.45 - Evaluation of grain yield and its components under drought stress during grain filling period in durum wheat

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Drought stress during the reproductive growth stage is a major limiting factor for durum wheat grain production worldwide especially in the arid and semi-arid regions. Field experiments were conducted to determine late drought stress effects on grain yield and its components of durum wheat in 2002 and 2003. Eight CIMMYT lines were grown under non-stress conditions and late drought stress conducted without irrigation from anthesis in two separate randomized complete block design. Day to maturity, seed filling period, plant height, spike length, number spike per m², number of kernels per spike, kernels weight per spike, 1,000 kernel weight, harvest index and grain yield were evaluated. Means of the traits significantly reduced under drought stress compared to non-stress condition. Plant height and harvest index were the less sensitive while number of kernels per spike and kernels weight per spike were the most sensitive traits to drought stress. Positive phenotypic and genotypic correlations were obtained in both conditions between grain yield and the characters except plant height under non-stress condition and plant height and spike length under drought condition. Path analysis identified kernels weight per spike and grain filling period having the greatest positive direct effects on grain yield, while plant height and 1,000 grain weight having the greatest negative direct effect on grain yield. Under drought condition high direct effects were contributed by day to maturity, harvest index and number spike per m² with positive association to grain yield, while number of kernel per spike and spike length displayed a negative direct effect on grain yield. The implication of these results in durum wheat breeding programs to improve grain yield under non-stress and drought stress conditions reveals that different traits should be considered as selection criteria under each of the environments.

P 2.46 - Soil moisture monitoring using wireless sensor network for wheat drought research

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Agricultural production in the dry areas of the Central and West Asia and North Africa regions (CWANA), which is mainly under rain-fed conditions, is vulnerable to drought and far from sufficient to meet the food demand of the rapidly growing population. Drought research requires data not only on precipitation but also on actual soil moisture of fields where crops are grown. Crop research requires more information on water dynamics in soil profile and plant x soil moisture interaction which can be obtained through monitoring of soil moisture content under drought stress. Crop germplasm tolerant to different levels of soil moisture deficit can be evaluated in breeding programs. Measurement of soil moisture in the field is simple but of labor-intensive. Recently a prototype of an automatic monitoring apparatus of field data with a mini-computer with web browser, sensors (camera), Ad-Hoc wireless LAN and battery supply has been developed. The prototype known as “Field Server” allows for data collection with real-time monitoring, multi-channels, and multi-sites, from long distance. Remote access to the network of “Field Servers” equipped with wireless LAN and internet may accelerate the development of early warning system for drought. This paper is a case study on a soil moisture monitoring system for evaluating drought tolerance of wheat crops at ICARDA.
P 2.47 - Relation between radiation interception and water use by potato and green pepper under drought conditions

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A combination of high irradiance, high temperature and water stress (i.e. drought) is common during spring and summer under Mediterranean and other semi-arid conditions. Any stress leads to immediate plant responses, which are usually characterized by detrimental decreases in rates of physiological processes like photosynthesis and transpiration. Potato and green pepper are two of the important cash crops on irrigated land in Tunisia. Some of the major production problems of these crops are proper irrigation, high radiation and temperature, since they are traditionally crops that develop their phenological cycle during spring (potato) and spring and summer (green pepper). Use of agrometeorological information in crop production can promote the fullest possible exploitation of the climatic resources. Generally, two concepts are used to quantify the capacity of the crop to assimilate and grow: the concept of transpiration driven biomass production (WUE concept) and the concept of absorbed radiation driven biomass production (RUE concept). In the present work, two field experiments were carried out to analyze the growth of potato and green pepper in terms of: (a) radiation interception; (b) water use; (c) efficiencies of conversion of absorbed radiation and evapotranspiration into biomass and (d) dry matter accumulation. Growth analysis, total solar radiation, water use and leaf area index were measured. In order to investigate whether LAI level affects water and light use by plants, diverse conditions of water-stress were carried out for each crop. For potato, where trickle irrigation is used, the experiment consisted of three irrigation levels, 100, 75 and 50% of the crop evapotranspiration ETc. For green pepper, where small basin irrigation is used, four irrigation levels induced by water distribution variability into the field are considered. According to soil moisture measurements during growing season, evapotranspiration levels ranged from 57 to 74% from crop evapotranspiration ETc. The two crops are show to have contrasting growth patterns. For potato, maximum LAI values ranged from 4.2 to 5.3. The overall means RUE and WUE was 2.6 g MJ PAR⁻¹ and 5.1 kg m⁻³, respectively. For green pepper, maximum LAI values ranged from 2.5 to 4.3. The overall means RUE and WUE was 1.8 g MJ PAR⁻¹ and 2.0 kg m⁻³, respectively. From similitude among crops dry weight responses to the cumulative intercepted PAR [TDW = f(PARi)] and to the cumulative evapotranspired water [TDW = f(ETa)], a linear relationship was established between these two parameters. The slop of this regression [ETa = f(PARi)] were not significantly different between water application levels which is 0.51 10⁻³ m³ MJ PAR⁻¹ for potato and 0.83 10⁻³ m³ MJ PAR⁻¹ for green pepper. These results provide information for predicting potato and green pepper biomass and evapotranspiration from a common and an easily measured experimental parameter PARi (i.e. LAI).
P 2.48 - Expression of drought adaptation traits in a random population of sorghum grown in
Niger

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Sorghum is an important human food crop in Niger and other West African countries characterized by poorly
rainfed agriculture on soils with low fertility. Improved sorghum cultivars have been developed or introduced
and released with limited success due to insufficient adaptation to the harsh growing conditions. On the other
hand, there exists farmer-preferred landraces of sorghum with excellent adaptation to this environment. Our
project aims at understanding and utilizing the unique potential of so-called dune sorghums of Niger in
development of new cultivars with high and stable yields that may contribute significantly to food production.

Starting with a cross between late maturing landrace Mace Da Kunya (MDK) and early maturing breeding line
L153-5, more than 900 progeny were advanced to F6-F8 generations without selection. A random set of lines
from this population was characterized for germination, seedling vigor, plant maturity, height and grain yield on
sandy soil at the Maradi research station. Climatic conditions included good rainfall the first year and severe late
season drought the second year. Due to drought, there were shifts in population averages towards lower grain
yield, shorter plant height and earlier maturity. Early seedling vigor was good in both years, however plant death
was observed under drought. This pattern was also apparent in the two parents used as checks in the trials,
especially with MDK. The relation of plant maturity with grain yield in stress environments will be discussed.

P 2.49 - Response of corn yield to plant water stress caused by salinity and drought: a
comparison

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The effects of water stress, caused by salinity and by drought, were studied on corn grain-yield, in a semi-arid
region of the southern Italy. In the drought experiment, carried out in open field, the corn was grown during two
seasons, under three water conditions: lack of stress, mild and severe water stress. The three conditions were
obtained by scheduling differently the irrigations. In the salinity experiment, carried out on a lysimeter set-up, the
corn was grown during a season, on two soil types: loam and clay. Also, in the case of the salt stress, corn plants
were grown under three plant water conditions. The three conditions were obtained by irrigating at the same
time, but using waters of three different qualities: fresh water, containing 3.7 meq Cl⁻¹ and EC of 0.9 dS m⁻¹, and
two saline treatments containing 15 and 30 meq Cl⁻¹ and EC 2.3 and 3.6 dS/m, respectively, obtained by adding
equivalent amounts of NaCl and CaCl₂. The water stress during the whole growing season was expressed by the
WSDI (Water Stress Day Index). This index is based on pre-dawn leaf water potential, regularly measured during
the crop cycles. The same relationship between relative grain-yield and WSDI was found under drought and
salinity conditions. This result indicates that the corn yield response to the water stress does not change
according to the cause whether it is salinity or drought. The WSDI, proposed by Katerji et al. (2000), is a suitable
indicator for determining crop response to salinity and to drought.
P 2.50 - Combining ability of wheat genotypes for grain yield and plant height under optimum and moisture stress conditions

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To estimate and compare general (GCA) and specific combining ability for grain yield and plant height in wheat, two experiments were conducted under stress (restricted irrigation) and non-stress (normal irrigation) conditions. In each experiment, 28 F2 populations along with 8 parental genotype of an 8 × 8 half diallel crosses, were grown in a complete block design of experiment with three replications. The results showed a highly significant difference between genotypes and also between environments for yield per plant and plant height. The genotype x environment interaction was also significant for both of the traits. For plant height, variance of GCA was significant in both stress and non-stress conditions. However variance of SCA was significant only in non-stress environment. Cultivars Ghods, Falat, Darab and Chamran had negative and significant GCA effects for plants height. High and negative SCA for plant height was observed in some crosses both in stress and normal conditions. So, selection of dwarf plants is expected to be possible in progeny populations of such crosses in both the environments. In non-stress environment, GCA and SCA covariances for grain yield were highly significant. However in stress condition, only SCA variance for this trait was significant. In normal irrigated conditions, the cultivar Falat, showed positive and significant SCA effects for yield per plant, but in stress condition none of the genotypes showed significant SCA effects for this trait. Crosses Falat × Ghods and Arvand × Barakat showed positive and significant SCA effects for yield per plant in non-stress conditions. The SCA effects of other cross combinations for this trait were not significant in both restricted and normal irrigation conditions.

P 2.51 - Drought effect on potato tuber number and weight and their relations

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For evaluation of three potato cultivars (Marfona, Agria and Draga) to drought effects, an experiment was conducted. Irrigation was arranged in four intervals (6, 10, 14 and 18 days) in horizontal plots. After emergence, irrigation continued 6 days until 50% flowering and then drought treatments began. At the end of flowering, irrigation intervals decreased to 6 days. Sampling was made every other week and vegetative attributes, stolon number and tuber number and weight were measured. Results showed that all attributes were decreased in comparison with controls. Root dry matter and tuber weight losses had a positive relation with drought intensity. In spite of yield decreasing, tuber number at the end season had no significant differences in irrigation levels. Draga in mid-season had the highest tuber number and the least tuber weight. Increasing stress intensity led to increasing the percent of small tubers. However, stress had no effect on seed tubers percent but marketable tubers percent decreased. Increasing stress intensity led to increasing little and seed tubers weight percent and decreasing marketable tuber weight percent. Little seed percent increasing may relate to increasing stolon produce or decreasing tuber bulking and filling. Agria produced highest tuber number percent and marketable tuber weight percent.
P 2.52 - Water use efficiency of raspberry (Rubus idaeus L.) in lowland conditions under regulated deficit drip irrigation

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Experimental work was carried out in the period 2002-2004 in 400 m² raspberry plantation of the floricane-fruited "Lewlin" variety. In the lowland conditions of the Plovdiv region in Bulgaria, with relatively high temperatures and low air humidity, seven irrigation treatments were studied in four replications. During the main phenophases - 1) intensive growth; 2) blossom; and 3) fruiting - water was applied in amounts of 100, 75 and 50% of ETc. Fertilizers were applied through the irrigation water, the fertilization rate being equal for all treatments. The annual yield, averaged over the three experimental years, was in the range 1001-1472 kg/da. Compared to the control (100% ETc), yield decreased significantly only in most severe variants V2-50 and V3-50. For the period 2004-2004, the average mass of one fruit was 2.5-2.7 g. Only in variant V3-50 fruit diminished significantly. Raspberry fruit was largest at first harvestings of each season, 3.0-3.4 g. Regulated Deficit Irrigation (RDI) suppressed significantly growth only in variants V2-50 and V3-50. In most variants, water use efficiency (WUE) was about 2.0 kg/m³. V3-50 resulted in slight increase in WUE - 2.1 kg/m³, while in V2-50 WUE was only 1.7 kg/m³. Hence, with "Lewlin" cultivar application rates can be reduced by 75% without negative impact on yield and fruit quality. Because of the frequent rainfalls in the spring, in the phase of intensive growth the reduction may be even 50%.

P 2.53 - Usefulness of drought tolerance parameters in breeding for drought tolerance

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Today water is becoming an increasingly scarce resource and the situation is going to be worse in the future. Since only about 70% of the available water is used in agriculture, breeding for drought tolerance must receive the top priority for achieving food security and saving water globally. For successful breeding for drought tolerance, the plant breeders have to make many crosses for combining desirable traits. Subsequently, the large segregating populations (F2-F5) are grown for selection of desirable traits under uncontrolled natural environments. Under such situations, the use of various drought tolerant parameters in breeding needs to be investigated. Jackson et al. (1996) have surveyed the impact of physiological research on crop breeding where he mentioned that there has been little utilization of crop physiologists to identify suitable environments for selection. Physiologists have identified a wide range of morphological, physiological and biochemical traits that contribute to yield improvement of crops in drought-prone environments. However, there are only a few examples of success using physiological characteristics in breeding programme (Turner et al. 1997). There are various reasons for this. Only few of the characteristics have been studied in terms of their fundamental significance to seed yield (Passioura 1981). Drought tolerant traits are recorded at different growth stages and they are highly affected by environment, whereas a breeder has to grow plant populations in natural field conditions which face environmental fluctuations over the years and locations. For their reliability the measurement of these traits is generally done under moisture stress conditions only. However, the large breeding populations being handled by breeders cannot be grown under controlled conditions like rain-out shelters, etc. Moreover, recording of these traits are mostly difficult, laborious and costly and therefore cannot be recorded on a huge number of plants in segregating populations. Some of the important drought resistant traits such as osmotic adjustment, ascorbic acid accumulation, root density and depth, stomatal control, lethal water potential, proline accumulation, etc., are difficult to screen for and the usefulness of some of these in yield improvement is questionable (Turner et al. 1997). The reliability or dependablear of some of these traits in conferring drought tolerance is also not clear. What the breeders need are the reliable and dependable drought tolerant parameters which can be scored even in the non-drought conditions and should be easy to score on large numbers of plants besides also being not too costly. The potential technique, which meets these requirements and is independent of environmental factors, is the use of molecular markers and QTLs. Moreover, the indirect selection through molecular markers for a trait is more effective and efficient in crop improvement programmes. Therefore, the need of the hour must be giving more emphasis on the identification of molecular markers/QTLs linked to the drought tolerance as such or to the drought tolerant traits.
Increased regulations restricting water use, competition for water with large urban areas coupled with extreme temperatures and drought have placed a large strain on the aquifers and rivers, and therefore on the livelihood of farming communities. In addition, consumer demand for high quality, healthy and nutritious vegetables has increased. Our experiments emphasized the application of subsurface drip irrigation (SDI) technology in order to save water, maximize production and improve overall quality of high-value vegetable crops. Irrigation treatments ranged from 100 to 50% crop evapotranspiration rates (ETc). We focused on three crops: diploid and triploid or seedless watermelons, short-day onions and specialty peppers. Deficit irrigation did not decrease soluble solid content and significantly increased flesh firmness in triploid compared to diploid watermelons. Fruit lycopene content increased with maturity at all irrigation rates. Deficit irrigation (0.5 ETc) reduced yield, but it had less effect on fruit lycopene and size of seedless watermelon cultivars. In onions, SDI combined with containerized transplants increased water use efficiency, size, flavor components and profitability as compared to SDI and direct seeding. In peppers, SDI with plastic mulch increased marketable yields, water use efficiency and vitamin C as compared to the traditional furrow systems. Deficit irrigation applied through SDI technology is a critical strategy to reach significant water savings in one season and to enhance final product quality of vigorous cultivars.

The solar greenhouse production, with its higher payback and economic benefit and intensive labor requirement that is suitable for the Chinese actual conditions, has just becoming a new growth point in developing rural economy and adjusting industrial structure in the western region of China. With the development of greenhouse production that take sunlight greenhouse as the subject in recent years, because single growing variety of vegetable, continuous cropping for many years and unreasonable management of fertilizer and water etc., a series of bad phenomena-continuous cropping obstacles - had been appeared, such as soil environment degradation, output reduce, crop disease aggravation. This threatened the sustainable development of solar greenhouse production and become last urgent problem waiting to be solved in production. Based on the experiment of different rotation system between cucumber (Cucumis sativus L.) and other different crops which were conducted in solar greenhouse on Loess Plateau, of Baota district of Yanan, north of Shaanxi Province in 2001-2003, this paper analysed the soil microbe of different rotation system and it effect on cucumber productivity. The results shown that after the cucumber of winter-spring stubble was harvested, there were significant effects of different rotation systems on the soil microbe reduce. The soil microbe was the lowest in fallow; the second lowest was planting cowpea or other leguminous crops. This paper illuminated the degradation process of soil quality from soil physical, chemical and biological, analysed the main degradation reason for soil quality in solar greenhouse on Loess Plateau, at the same time, put forward the approaches to keep soil quality and to maintain solar greenhouse production sustainable development. The highest cucumber yield could be get to plant cucumber after planting corn for green manure, black-bean for green manure or planting cowpea, then higher cucumber yield could be get after fallow in summer, the cucumber yield was lowest to plant cucumber after planting tomato and rape. This paper put forward that it was efficient rotation system for preventing and overcoming continuous cropping obstacle to use rotation system of cucumber with corn for green manure, black-bean for green manure or planting cowpea.
P 2.56 - Adapting crops to future dryer climates: using crop models to study the potential of different plant traits to increase yield in water limited environments

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Due to climate change, plants will face warmer and often dryer climates so there is an increasing pressure to adapt cropping systems to water limited environments. For the wheatbelt in SW Australia, rainfall is predicted to decline by 30% and temperatures will increase by 2-4 °C in the coming century. Several changes in plant traits have been suggested to improve crop production in water limited environments but it is often hard to test in the field what the contribution of trait changes is to improved yield. We used a crop model to test whether increased rooting depth, early vigour and higher transpiration efficiency improve plant production. We simulated wheat cropping systems at three different sites on a north-south transect in the Mediterranean environment of SW Australia. We used both historic weather and transformed climate data to simulate future climate change. Increased transpiration efficiency improved yields for both current and future drier climates, especially on clay soils. Results suggest that increased rooting depth is a good adaptation to global warming because positive effects of increased rooting depth improved with higher temperatures. Increased early vigour had little effect on yield under the current climate. However, at higher temperatures under moderate water stress early vigour can improve production by more than 20%, especially if fertilizer input is increased. In conclusion, our analysis shows that crop models are a useful tool to determine which changes in plant traits can improve plant production in water limited environments for both current and future climates.

P 2.57 - Technology option for increasing rainfed rice production

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In rainfed ecosystems, broad casting of seeds results in uneven and poor plant stand and higher weed intensity. Introduction of mechanized seed cum fertilizer sowing facilitates placement of seeds at optimum depth besides improving fertilizer and weed management. An experiment conducted in 12 different farmers' fields demonstrated the superiority of seed cum fertilizer seed drill sowing compared to farmers' method of broadcasting. A grain yield of 3.830 kg/ha was obtained under seed cum fertilizer seed drill sowing compared to 2.799 kg/ha farmers' broadcasting method. Thus, introduction of mechanized seed sowing offers scope to increase the production potential of rainfed rice production by uniform spacing between plants and reducing weed intensity.
P 2.58 - Rate and duration of kernel filling and grain yield of barley genotypes grown in dry areas of Iran

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Barley is cultivated on 1.5 million ha under variable agro-climatic conditions mostly in rainfall areas prone to terminal drought stress in Iran. The grain yield and rate of kernel weight of barley genotypes grown in the dry areas of northwest Iran in 2002-03 and 2003-04 were measured to determine how the rate and duration of kernel filling and position along the spike are differed among the old and new breeding lines under drought stressed and irrigation conditions. Significant differences in grain yield occurred under drought stressed conditions and grain yield ranged from 1.72 to 0.77 t ha⁻¹ 'Gara Arpa' and 'Sahand' old common cultivars produced the highest yields. Under irrigation conditions, grain yield ranged from 5.04 to 3.24 t ha⁻¹ and 'Yesevi-93' a new breeding line, Sahand and Gara Arpa were the top three high-yielding genotypes, respectively. Kernels weight was varied along the length of the spike with kernels from the middle part of the spike significantly heavier than those from the lower and upper parts. Rate and duration of kernel filling differed significantly between genotypes under drought stressed conditions. Most genotypes had a high rate of kernel filling and high grain yield. Under irrigation conditions, differences in trends of kernel development were not similar to drought stressed conditions. Considerable variation for rate and duration of kernel filling and yield composition exists within the barley gene pool with most of the high yielding genotypes originating from ICARDA, which can be used for increasing grain yield in the dry areas of Iran.

P 2.59 - Evaluation of durum wheat biodiversity for productivity in mild water-stressed environments

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The Mediterranean region is particularly sensitive to drought and potentially very vulnerable to future climate changes. A general tendency toward decreasing mean rainfall has been observed and if continued, is expected to affect future crop production in the Mediterranean parts of Europe. A work aimed to study the effects of different levels of water availability during the whole life cycle on plant production is in progress on a collection of durum wheat genotypes including modern varieties with high productivity value, local populations, old cultivars and genotypes selected in arid environments. The selected genotypes have been grown in Foggia, an environment characterised by a mild water stress, under rainfed conditions or with supplementary irrigation for two years. The phenotypic characterisation based on the analysis of yield performance and other agronomics traits under the different tested conditions allowed to identify genotypes with good yield and a minimal G x E interaction, so as genotypes with both high yield potential and high yield stability. These genotypes could be considered very close to the durum wheat ideotype for environments characterised by a mild water deficit, such as those of Mediterranean Europe, where durum wheat is traditionally grown.
P 2.60 - Does reduced-tillering improve kernel size stability in wheat?

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Twenty percent of Australia’s wheat crop is grown in the northern Australian wheat belt. Summer rainfall predominates in this region, with the wheat crop grown largely on stored soil moisture. Temperatures rise and water becomes limited during grain filling through to maturity. While these conditions often reduce grain yield, they may also increase the proportion of ‘screenings’ (small or shriveled kernels) in the crop. This reduces farmer profitability as crop payments are penalized as screenings increase. Excessive tillering, particularly on wider row spacings, may contribute to this increase in proportion of small grain. Previous studies suggest that the incorporation of reduced tillering genes encourages larger stems, higher harvest index and increased kernel weight and therefore could improve harvest quality. A series of field experiments have been sown to investigate the value of the tiller inhibition (tin) - reduced tillering gene, in maintaining large kernel size under water limiting conditions. Key hypotheses are that reduced tillers would promote root growth and hence more water become available to the plants, reduce inter-tiller competition resulting in a population of larger productive tillers, increase assimilate availability to the developing spike and spikelets ensuring large potential kernel size, and increase assimilate availability during flowering and grain filling to fill kernel to its potential size. A detailed physiological study is being conducted on the performance of two genetically contrasting sets of near-isogenic lines containing the tin gene. Lines were established at 3 densities (9, 45, and 100 plants m⁻²), with the aim of identifying whether for a given maturity spike number m⁻², kernel weight is larger in reduced-tillering than free tillering lines, and to understand the underlying physiological and or morphological basis for the difference in kernel size. Furthermore, a total of 145 sister lines segregating for tiller production derived by crossing the tin gene into four contrasting genetic backgrounds have been sown in contrasting well-watered and water-limited environments. The aim here is to examine the relationship between tiller number and grain number, and how differences in spike number may influence kernel size in lines genetically contrasting for high and low tiller potential, and to examine how robust this is across environments, management regimes and genetic background.

P 2.61 - Water potential of Cenchrus ciliaris L. a perennial grass of arid regions

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Plants of arid ecosystems are subjected to prolonged periods of drought. The drought resistance of species occurring in these regions is conferred on them by both adaptations mechanisms. This study was undertaken to examine the drought resistance among different Cenchrus diuris accessions growing in the south of Tunisia. Four Accessions (A1, A2, A3, A4) of this species were collected from different sites in southern Tunisia. Leaf water status were made from September 2003 to June 2004 in an attempt to identify differential responses to stress conditions. Water potential (predawn potential: \( \Psi_{PD} \) and minimum potential: \( \Psi_{MIN} \)) was obtained with a Scholander bomb. All accessions held constant water potentials throughout the watering period. Diurnal patterns of water potentials in winter were very similar between accessions, and ranged from –1.5 MPa (\( \Psi_{PD} \)) to –3 MPa (\( \Psi_{MIN} \)) at midday. Annual kinetics of predawn and minimum potential observed during the year, showed that lower water potentials were observed in summer (–3 MPa). As would be expected, higher water potentials (–1 MPa) were observed in the winter due to the high level of precipitation that occurred. Statistical comparison of water potential across plants indicated that differences among accessions were not significantly different (p > 0.05). The difference \( \Delta \Psi \) (\( \Delta \Psi = \Psi_{PD} - \Psi_{MIN} \)) remained approximately constant. No differences were found between the performances of Cenchrus diuris accessions under the simulated rainfall regimes. In the context of potential utilization for the rehabilitation of degraded ecosystems, Cenchrus diuris appears to possess several properties that lead to greater tolerance of water stress.
P 2.62 - Improving wheat yield and quality grown in sandy calcareous soil in middle Egypt

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An investigation was carried out in the field of the Agricultural Research Center at Shousha, Minia University, Egypt in two growing seasons to study the effect of filtermud (sugar industry waste) applied either alone or in combination with nitrogen fertilizer to sandy calcareous soil on wheat yield and uptake of N, P and K. The application rates of filtermud were: 0, 3, 6 and 9 ton/fed., while N rates were: 0, 50, 75 and 100 kg/ fed. Results indicate that grain yield, straw, concentration and uptake of N, P and K by wheat grains and straw were increased due to filtermud and N fertilizer application either alone or in combination. The increase was proportional to the increase in application rate. Application of 9 tons of filtermud + 100 kg N/ fed. showed the most favorable effect on increasing yield and nutrients uptake by wheat plants grown in sandy calcareous soil in middle Egypt. The increase in uptake of N, P and K by wheat grains and straw markedly improve the nutritional value of grains as human feed and straw as animal fodder.

P 2.63 - Salinization-water logging approach and mole drainage under saline groundwater in low permeable clay

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Heavy clay water-logged salty soils associated with highly saline ground water constitute a challenging problem. The solution must achieve lowering the water table at the end of the irrigation intervals, accelerating the downward movement in the surface layers, so that irrigation water constitutes a temporary front separating the saline ground water table from the root zone. The soil must not be left fallow for a long time. Since the saline ground water is submerging the subsurface layers of the soil profile, the fact that no risk of soil salinization during irrigation period does not seem to hold true. The restructuring/horizontal leaching may provide a viable field technique for reclamation of poorly permeable saline-sodic swelling soils. Wider spacing combined with secondary drainage treatment such as moling, subsoiling or deep ploughing is recommended.
P 2.64 - Soil and water utilization for maximizing effectiveness of maize as a protective crop for tomato in environmental stress conditions

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Toshky is a new area in the southern part of Egypt. Recently, a national project is interested in cultivating these lands to get clean agriculture free from pollution. The intercropping is one of the important factors to increase the income and may protect another crop from damage. The aim is to study the source as well as the doses of phosphate in combination with intercropping by using maize as a protective crop for tomato traits and production in conditions of environmental stress. The experiment was carried out for two years during 2000/2001 and 2001/2002 seasons in randomized complete block design. The treatments are different mainly in phosphate sources (natural rock phosphate and super phosphate) and doses. Transplanting dates for tomato (castle rock) hypered were on 25th and 30th December in both seasons 2000/2001 and 2001/2002, respectively, while sowing dates of maize was on 15th and 20th February in the two seasons, respectively. Tomato was transplanted in lines 100 cm width, each with two drips 50 cm between each drip. Maize was planted in hills spaced 25 cm on the other side of the drip. Soil varies from loamy to sandy loam; salinity, organic matter and soil fertility is very low and soil reaction tends towards alkalinity. The soil taxonomy could be classified as Typic Xerofluvants loam, mixed hyper thermic to Typic Torripsamments, sandy loam, mixed hyperthermic. Intercropping tomato with maize saved irrigation water by 40% comparing to solo treatments. Tomato fruits are affected significantly by intercropping tomato with maize and phosphate sources and doses. The damage to tomato fruits was decreased and marketable yield increased. These could be attributed to the height of maize plants that acts as a shadow on tomato plants and protects the fruit from the sun and reduces the effect of direct burning on fruit. Phosphate fertilizers may affect maize but there is no significant effect on maize yield. The greatest advantage for using intercropping is to maximize usage unit of land and water to produce maximum production.

P 2.65 - Optimal allocation of irrigation demand and its impact on groundwater - a case study in Bangladesh

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The operation and management of irrigation are of growing concern all over the world. This is especially true for developing countries where the need to enhance the agricultural productivity is coupled with decreased availability of water owing to rapid industrialization and ever increasing irrigation demand. The study area is located in the northwestern part of Bangladesh and covers app. 475,300 ha with a cultivated area of app. 307,300 ha. The main problem of the study area is that the current irrigation setup fails to bring all the cultivable lands under irrigation. During dry season most of the shallow tubewells are dry due to excessive withdrawals of groundwater, resulting in a tremendous scarcity of irrigation water. A dynamic programming technique has been used to find the optimal cropping pattern and optimal scheduling of irrigation to maximize the net benefits of crop production for deficit irrigation as there is a lot of conflict which arises between water supply and demand in a multi crop irrigation scheme. From the optimum cropping pattern, an irrigation demand has been calculated. A groundwater flow model has been developed to find the effect of the present irrigation system and optimum irrigation requirement. The present study will help to define the abstraction of safe and sustainable yield of groundwater to maximize net benefits, irrigation scheduling during dry season when there is a lot of scarcity of water for irrigation, the most effective cropping pattern to reduce the pressure on groundwater.
Evaluation effect of drought stress and plant density on ecophysiological traits of three lines of safflower in Isfahan summer planting

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In order to study ecophysiological traits of safflower at the different intensities of drought stress in Isfahan summer planting, three lines of safflower selected from Isfahan local (Isfahan–8, Isfahan–24 and Isfahan–44) and three plant densities (31.20 and 13.3 P/m²) with the four irrigation regimes: three irrigation regimes after 70, 140 and 210 mm evaporation from class A pan until physiological maturity and other after 140 mm evaporation until complete flowering were used in a summer planting in northwest of Isfahan. The experiment was on randomized complete block design with a split-split plots layout with three replications during 2001-2002. In this study, stress intensity (SI) calculated and the effects of drought stress on the ecophysiological characters included Grain Water Use Efficiency (GWUE), Biomass Radiation Use Efficiency (BRUE), Grain Radiation Use Efficiency (GRUE), Oil Radiation Use Efficiency (Oil RUE), Leaf Area Index (LAI), Specific Leaf area (SLA) and Plant Damping Rate (PDR) were evaluated. The results showed that parallel to a reduction in water use in safflower canopy (lower than after 70 mm), there was an intensive stress in canopy (SI was about 0.45 and 0.42, in 80 and 81 years, respectively, in after 140 mm treatment. although with more decreased of water use, increase of the intensive stress was very little. Also drought stress caused GWUE, BRUE, GRUE, Oil RUE, LAI and SLA reduced but PDR was increased.

Potato yield response to saline water management under drip irrigation in arid conditions of southern Tunisia

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A field study was conducted in southern Tunisia to determine the effect of irrigation regimes with saline water on growth, yield and water use efficiency of potato (Solanum tuberosum L.). The cultivar “Spunta” was grown on a commercial farm during spring and autumn seasons in a sandy soil and irrigated with water having an ECi of 3.25 dS/m. For both cropping periods, a complete randomized block design with four replicates was used to evaluate five irrigation regimes. These consisted of a daily irrigation regime (100-D) at 100% of crop evapotranspiration (ETc) and four low frequencies (irrigated when readily available soil water had been depleted) application treatments with a range of water deficits from 40 to 100% of accumulated ETc (100-L, 80-L, 60-L and 40-L). Findings are globally consistent between the two experiments. Soil salinity values were highest midway between the emitter and the margin of wetted band for the 100-L and 100-D treatments. With 40-L and 60-L treatments, the greatest values of soil salinity were recorded at distances of 7 and 15 cm from the emitter, and 10 and 20 cm from the drip line. For both seasons, growth decreased significantly as the amount of applied water decreased from 100 to 40% of ETc. At the 100% ETc level, irrigation frequency did not affect growth parameters. Yield was higher in spring than in autumn season. In both seasons, maximum yields were achieved with 100-L, although no significant differences were observed with the daily irrigation treatment (100-D). Yield decreased slightly when applied water was reduced by 20%. However, reduction in yield and quality were significantly important when restrictions reached 40% ETc. The reduction in yield was attributed to reduction in tuber number and weight. Water use efficiency of potatoes obtained in our experiments corresponds with values reported in the literature and was affected by cropping season and irrigation treatments. These observations could have an effect on methods for care and irrigation of potato in arid conditions of Tunisia.
P 2.68 - Interaction of nutrient elements and drought stress in cultivars of Brassica napus

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Drought is caused by an imbalance between evaporation, including transpiration and rainfall. Plants during their life cycle, examine water stress due to low soil moisture availability, high temperature and high solar irradiance. Plants also grow in arid and semi-arid regions which tolerate water stress. There is considerable diversity within species, cultivars and genotypes, as the result of both natural adaptation and breeding. Rapeseed (Brassica napus), which have a high percent of oil and protein, is an oil crop which has been considered for production in Iran during the past ten years. Canola production appears to be a turning point in producing the needed vegetable oil in the country since, currently, 90% of the food oil consumption is imported. Evidence shows that Brassica species and cultivars have different responses to water stress. In this study, the physiological approaches and maximizing of grain yield from different Brassica cultivars and lines were evaluated. The research had continue from three years in yield and Greenhouse. In the first experiment 48 cultivars and lines were evaluated in randomized complete blouk with four replications to water stress. Relative water content (RWC), leaf water potential, yield and component yield were measured. Among Rapeseed cultivars and lines, Hyola-42, Syn-1 and Pf7045.01 were superior and Symbol and Mohican were more sensivity to the cultivars and lines in response to water deficit. Comparison of five cultivars and lines in different moisture stress (0, 25, 50 and 75 % of field capacity) showed that Hyola-42 cultivar is more tolerant than Symbol and Mohican cultivars. This may be due to accumulation of compatible solutes such as proline. Water stress decreased oil percent, oil yield, yield and component of yield in plants. Search in greenhouse showed that water stress decreased water USE efficiency. But increased root and shoot ratio. Also harvest index (HI) decreased in water deficit. In the split plot design, water stress increased nitrogen concentration in leaves, but decreased phosphorus, potassium, boron, zinc and sulfate. In conclusion, differences exist between rapeseed cultivars and lines in response to water stress and this may be due to different accumulations of compatible solutes, relative water content and leaf water potential of leaves.

P 2.69 - Comparative effects of partial root-zone drying (PRD) and regulated deficit irrigation (RDI) on physiological and biochemical parameters in grapevines

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The effects of partial root drying (PRD) and regulated deficit irrigation (RDI) on water relation, gas exchange and abscisic acid (ABA) concentration was examined in own-rooted plants of three different grapevines cultivars (V. vinifera L.) which were grown with roots split between two soil columns. The plants were subjected to one of three irrigation treatments: well watered (WW-control) receiving 100% of plant transpiration, PRD with half of the root system exposed to soil drying and the other half kept well watered and RDI with 50% of plant transpiration supplied to both the sides of the root system. Results indicated that stomatal conductance of vines under PRD and RDI irrigation was significantly lower compared with control while there were no significant differences in photosynthetic rate. Sap flow as well as leaf water potential was significantly lower in PRD and RDI treatments compared to control, but without any differences between PRD and RDI. The reduction in transpiration rate in both PRD and RDI treatments in relation to the maintenance of photosynthetic rate resulted in significantly higher values of intrinsic water use efficiency.
P 2.70 - Study of water stress effect on water use efficiency of two rapeseed (Brassica napus L.) cultivars

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In order to study the effect of water stress on economic and biologic water use efficiency in two rapeseed cultivars, the experiment conducted into factorial split plots design in the basis of complete randomized block with 3 replications in two regions of Iran (Pakdasht and Karaj). There were two factors irrigation intervals (45, 65 and 85 mm evaporated of pan) and water amount in 3 levels (60, 80 and 100 % of evaporation) into factorial as main factor and cultivars in 2 levels (Talayieh and PF 7045,91) as subfactor. The results indicated that interaction effects of irrigation intervals and water amounts had significant difference at 1% level on Economic and biologic water use efficiency in two regions. In irrigation after 45, 65 mm evaporated of pan when the water consumption decrease to 60%, maximum amount of economic and biologic water use efficiency was 866.6g/m³ and 2439g/m³. Interaction effect of irrigation intervals and cultivars had significant difference at 1 level, when irrigation intervals or irrigation distance reduced, the means of economic and biologic water use efficiency increased, both these amounts in PF 7045,91 was greater than talayieh, the maximum Economic water use efficiency of PF 7045,91 and talayieh was 769.3g/m³ and 598.0g/m³ and biologic water use efficiency was 2099.0g/m³ and 1782.0g/m³. Interaction effect of water amounts and cultivars showed significant difference at 0.01 level of probability. When water amount decreased to 60% mean of economic water use efficiency of PF 7045,91 and talayieh increased to 603.4g/m³ and 489.5g/m³, biologic water use efficiency increased to 1917.0g/m³ and 1734.0g/m³.

P 2.71 - The role of pre- and post-anthesis water availability in predicting yield and protein content in malting barley

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Northern European growing conditions are characterised by development and growth enhancing long days and cool growing conditions, but also unfavourable distribution of precipitation. Drought interferes growth especially in early growing season when yield potential of cereals is determined. Namely, 86% of variation in barley yield is explained by grain set and only 8% by grain weight. Barley is especially prone to yield losses, because it is the most early maturing cereal species that is not able to compensate for even only temporarily unfavourable conditions. In MTT Agrifood Research Finland model launched for free access in internet (www.mtt.fi/ktl/pkm/satoennustehttp://www.agronet.fi) was developed to predict barley yield and grain protein content. Some twenty years’ multi-location data of MTT Official Variety Tests was used to build up the model, in which barley development is divided into several phases according to accumulated temperature. Barley response to meteorological parameters is dependent on development phase. The major factor causing variation in yield and grain protein content is precipitation prior to heading. The model also indicates the critical regional and soil type dependent limits for pre-anthesis precipitation. When precipitation is less than the limit, grain protein content tends to elevate above the acceptance limits for malting, whatever the growing conditions are thereafter. For example, pre-anthesis precipitation is regularly less than 70-100 mm in areas producing major part of Finnish malting barley and this often results in increased grain protein content. This model is used by Finnish malting industry to anticipate their annual need for importing malting barley.
**P 2.72 - The sensitivity of plant water indicators in almond trees submitted to severe deficit irrigation**

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The aim of this study was to compare the sensitivity of different plant water status indicators when a severe water stress was applied, in order to be able to use them in irrigation scheduling. To do this, four-year-old field-grown almond trees were starved of water for 23 days, beginning on 1 September, while the control trees were watered daily to 120% of crop evapotranspiration. At the end of this period, the trees were watered again in the same way as the control trees. The indicators tested were midday stem water potential (SWP), midday leaf conductance (LC) and maximum daily trunk shrinkage (MDS) obtained from the trunk diameter fluctuations measurements. The results obtained demonstrated a high sensitivity to water stress in all 3 indicators. The average value for the control group during the experiment was -0.94 MPa, 280 mmol m^-2 s^-1 and 142 μm for SWP, LC and MDS, respectively. Suppressing irrigation lead to a significant response of these indicators with values averaging -1.90 MPa, 150 mmol m^-2 s^-1 and 420 μm. The relative differences between treatments increased during this period, reaching values of 485% for MDS, much higher than those reached for SWP (13%), and LC (60%). During the recovery period the values of MDS showed a 97.1% recovery slope, significantly higher than the other two variables (41.1 and 6.4% for SWP and LC, respectively). All this indicates that MDS shows a higher sensitivity in detecting water stress and could be used in the automatic scheduling of irrigation in young almond trees.

**P 2.73 - Physiological responses of Carrizo citrange citrus rootstock seedlings to salinity and drought stress**

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We studied the interacting effects of short-term (9 days) salinity and drought stress (DS) on leaf water relations, gas exchange parameters, leaf anatomy and carbohydrates in 1-year-old seedlings of Carrizo citrange [Citrus sinensis (L.) Osbeck x Poncirus trifoliata]. One week before beginning the drought stress, salinized and Salt+DS seedlings were watered with a nutrient solution containing 100 mM NaCl. After 9 days of withholding water from DS plants, all plants were watered with non-saline nutrient solution and their recovery studied. The minimum midday stem water potential (Ψstem) was lower in the DS than in Salt+DS seedlings. Net assimilation of CO₂ (A\textsubscript{CO₂}) was reduced in DS and Salt+DS. After recovery, values of Ψstem and A\textsubscript{CO₂} in the DS were similar to the control treatment but these values in the Salt+DS treatment remained lower. Leaf and root Cl⁻ and Na⁺ concentrations were higher in the Salt+DS treatment than in salinized plants. Salt+DS treatment had visible leaf burning, and microscopically, the thylakoid membranes of both palisade and spongy mesophyll cells were degraded. The starch concentration decreased in DS and salinized seedlings. These data underscore the importance of avoiding drought stress when seedlings are already salt stressed.
**P 2.74 - Using a growth model-based drought stress index for assessing drought tolerance in multi-environment sugar beet variety trials**

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Drought is a major limitation to sugar beet yield in many areas dependent solely on rainfall. Varieties differ in drought tolerance, but currently there is no mechanism to identify which are superior. We applied a method to evaluate data collected from multi-environment sugar beet variety trials (MET). The approach was to assign a drought stress index (DSI) to each trial, and then plot the regression of relative yield performance of each variety against a range of DSI. Varieties were classed according to their intercept (yield potential under low-stress conditions) and their slope (which indicates relative drought tolerance or susceptibility). The database consisted of 121 trials of 137 varieties conducted on 38 sites from 1989 to 1999. The DSI was based on the cumulative daily ratio of actual to potential evapotranspiration. The actual evapotranspiration for each trial was derived from a crop growth model using site-specific soil and weather inputs. Line comparison regression analysis revealed 20 varieties that showed significant positive or negative slopes, including seven varieties with average yield potential, but better than average yields under dry conditions. Conversely, there were 10 varieties that had good yield potential but showed poor performance under drought. ANOVA of trials testing some of these varieties within a single year showed that the ‘crossover’ behaviour was statistically significant and consistent across years. This approach of assessing MET data using the DSI as an environmental descriptor offers a simple way to select for drought tolerance or to cull susceptible varieties in current breeding programmes.

**P 2.75 - Characterization of photosynthetic events and associated changes in tea clones (Camellia sinensis L.) O. Kuntze under conditions of drought**

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In tea plantations, drought is known to cause about 20% of crop loss every year. The different clones of tea vary in their response to moisture stress. In order to find the response of recently developed tea clones such as TTL-1, TTL-2, TTL-4, TTL-5 and TTL-6 towards moisture stress, a comparative study was carried out with UPASI-2, a known clone for its drought tolerance and UPASI-3, a drought susceptible clone during the summer months (February to May, 2003 & 2004), directly in the field. Various parameters such as individual shoot weight (consisting of a banji), shoot length, leaf area, shoot banji ratio, relative water content of leaves, soil moisture potential and soil temperature were monitored in both irrigated and non irrigated sets of different clones on the 0, 20th, 60th and 100th day from the initiation of drought and on the 7th and 14th day during recovery from drought (i.e. watering after 100 d of stress). The chlorophyll and carotenoid content, chlorophyll fluorescence, CO₂ exchange, osmotic potential of leaves, proline, total carbohydrates, buffer soluble proteins and total free amino acids were also monitored in both irrigated and nonirrigated plants on the above mentioned days. On analyzing the results, the clones TTL-1 and TTL-6 appeared to be tolerant to drought. Even in non-irrigated conditions both these clones did not show any significant reduction in their Pn rates and they had developed high levels of proline, which might be helping these clones to tide over the moisture stress.
P 2.76 - Determine the efficiency of Balochistan’s traditional underground irrigation system Karez during the drought

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Objective: Determine the efficiency of Balochistan’s traditional underground irrigation system Karez during the drought

Design: A cross section study

Duration: 3 months (2004)

Subject and Methods: Total 20 Karez visited in five districts of the Pakistan’s largest province (Area 347000 Sq. Km.) and interviewed 120 old people with more than 60 years of age and living in that particular area. Questionnaires were developed in two local languages by the experts. These information collected includes, the underground mud made system of Karez, its beginning in the area (More than 1000 years back), its efficiency in normal rain fall/water conditions, effect of drought on Karez, Efficiency of Karez as compared to open irrigation channels during drought

Results: Being around 25-35 feet deep in the soil, the water loss through evaporation is very low, it’s a traditional method loved by every person in the area, efficient even during drought but due to continuous drought and low water level its highly affected, more over with the provision of electricity during last few years, tube wells installed in near by areas reduced water availability for Karez and thus its efficiency

Conclusion/ Recommendations: Due to ill planned installation of tube wells, many hundred years old traditional Karez system (Very low cost method) being destroyed drastically. A detailed study in all the province should be conducted and awareness campaign should be designed for the people/government installing tube wells without any planning that is causing very low water table level in the low rain fall areas. These areas do not have any other means of water (Irrigation/drinking) other than rains and underground water.

P 2.77 - Drought tolerance of some tomato genotypes cultivated under water deficit conditions

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Eleven genotypes of tomato (Lycopersicum esculantum Miller) were selected according to their rate of germination with various concentrations of common water stressors ABA (10⁻⁷ 10⁻⁶ 10⁻⁵ and 10⁻⁴) and PEG (1 to 6%). Regarded their respective germination rate, we have opted to use the following concentrations: PEG (3%) and ABA (10⁻³). Seeds of these genotypes were sowed in special bottle containing a solid substratum and placed in culture chamber (T 22-25 °C, RH 70%, 150 mmole S⁻¹, 12 -12 h) and watered during one week with drinking water. The plants were divided on two batches the first was maintained at 80% of field capacity and the second at 40%. Growth parameters (foliar area, leaves number, plant height and weight) physiological parameters (water consumption, RWC) and production parameters (Flower number, bundle number by plant and FW of fruits) were measured. Results show a great variation between the genotypes and the water deficit seems to affect the fresh weight of fruits more than the fruit numbers, for example. The PEG concentration seems to be correlated with results more than ABA.
**P 2.78 - Wastewater irrigation in drought management**

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The food requirement to meet the exploding population has been the prime need in the present world scenario. The gap between supply and demand for water is widening and is reaching such alarming levels that in arid and semi-arid regions the threat to human existence as a result of drought is increasing. The conventional attitude to a drought as a phenomenon of arid and semi-arid areas is changing because even areas with high average rainfall often face acute water scarcity. The drought is just not the scarcity or absence of rainfall, but is more related to water resource management. Irrigated agriculture will continue to play an unquestionable role in achieving food self-sufficiency, creating grain surpluses, stabilizing food prices, sustaining agricultural growth, absorbing labour force in rural areas, and alleviating rural poverty; all of which are vital for food security. The increasing resource degradation problems such as groundwater depletion, water logging, salinity and land degradation will add to the challenges. Mainly, food security of the poor will be at risk, as they would face severe resource constraints not only in accessing water, but also in investing in land and water management. Managing water for food security needs a multipronged approach. At the aggregate level, the irrigation water supplies and the demand for irrigation need to be balanced. The farmers should maximize production from available land and water resources with the least environmental consequences such as land degradation and groundwater depletion, through efficient resource use. Averting a water crisis is a massive undertaking that will require a combination of conservation, new technology, and cooperation among competing interests. In this context, the issue of irrigation of reuse of treated wastewater and other non-drinkable water sources during a drought obviously will be an important one. Water recycling and reuse are perhaps the cornerstone techniques for helping to drought-proof communities. “Recycling provides a safe and reliable source of water, and a good way to keep wastewater from entering the environment”. This paper highlights the benefits of reuse of treated paper mill effluent for irrigation especially in a wasteland area.

**P 2.79 - Irrigation in autumnal sugar beet: effects on root yield and plant growth**

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The Apulia region, in Southern Italy, is an important area for sugar beet cultivation: it is characterised by clay soils, hot-arid summer and winter-temperate climate. A way to escape summer drought is to sow sugar beet in autumn, with the benefit of reducing irrigation requirements. Irrigation can influence plant growth and yield: the aim of this research is to analyse the effect of irrigation regime on yield (root, total dry matter and sucrose), plant growth and leaf development. Data sets from 6 years of experiments of autumnal sugar beet submitted to different irrigation regimes were used to evaluate the effect of irrigation on i) fresh root, total dry matter and sucrose yield; ii) water use efficiency in the conversion in fresh root, total dry matter and sucrose; iii) leaf area index and dry matter accumulation. The effect of the irrigation regime was not significant for the great incidence of rainfall and water depletion in water balance, in respect to the irrigation water. In fact, irrigation supply was, on average, only 46.5% in the optimal regime and 32.9% in the reduced one of the seasonal water use. Consequently, the root yield did not differ between irrigation regimes, but sucrose concentration only, higher in the reduced treatment. The water use efficiency was higher in the reduced irrigation regime, especially in sucrose yield. The dynamics of leaf expansion showed higher and quicker LAI development in the optimal, while dry matter accumulation was, at harvest, more or less the same. A significant correlation was found between Etc/ETm ratio and fresh root yield. The results showed that it is possible to reduce and save irrigation water in autumnal sugar beet cropped in a Mediterranean environment without decreasing yield, allowing, consequently, to obtain a better use of water resources.
P 2.80 - Validation of a QTL for terminal drought tolerance in pearl millet

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Pearl millet [Pennisetum glaucum (L.) R. Br.] is the staple cereal of the hottest, driest areas of the tropics and subtropics. Several putative QTLs were mapped for grain and stover yield components and yield maintenance under terminal drought stress. Marker-assisted selection for these QTLs facilitated the development of near-isogenic QTL introgression lines (NILs). Nineteen homozygous NILs and their two parents (donor PRLT 2/89-33 and recurrent H 77/833-2) were testcrossed to five closely related male-sterile testers. The resulting 105 hybrids were evaluated for agronomic performance in replicated multilocation field trials during summer and rainy seasons of 2003 and 2004 at Patancheru and in Rajasthan (India). Across 14 environments, general combining ability effects of introgression lines ICMR 01029 and ICMR 01031 were substantially higher than recurrent parent H 77/833-2 for grain yield. Subsequent line-source moisture gradient experiments confirmed these findings and validated the effect of a major QTL for grain yield terminal drought tolerance from LG 2 of PRLT 2/89-33. Leaf gas exchange was measured under three moisture regimes corresponding to non-stressed control, intermediate and severe drought stress environments. In each of these three moisture regimes, the photosynthetic rates were significantly correlated with grain yield ($r^2 = 0.80$), suggesting the existence of genotypic differences in the response of leaf gas exchange to soil moisture availability. If confirmed, these findings could open new opportunities for better physiological understanding of plant water relations and more efficient trait-based selection of drought tolerant varieties in pearl millet.
P.281 - Influence of the patterns of root activity and soil water extraction in drought tolerance of two rootstocks citrus trees

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The influence of a deficit irrigation (DI) during the growing season on root activity (measured by soil CO$_2$ efflux in the root zone) and in the patterns of soil water extraction (measured by seasonal data of volumetric soil water content ($\theta_v$) in the soil profile (0-100 cm)) was analysed for mature Lane late (Citrus sinensis L. Osbeck) citrus trees grafted on two different rootstocks, Cleopatra mandarin (Citrus reticulata Blanco) and Carrizo citrange (Citrus sinensis L., Osbeck x P. trifoliata L. Ref. (DC), in SE Spain. Two treatments were applied for each rootstock: Control treatment, (irrigated at 100% ETc) for the full season and deficit irrigation (DI) treatment irrigated at 100% ETc, except during Phase I (May-mid June) and Phase III (mid September-December) of fruit growth when complete irrigation cut-off was applied. During the growing season, full irrigated trees (100% ETc) on Cleopatra rootstock maintained $\theta_v$ in the soil profile (0-100 cm) values significantly higher (24%) compared to control trees on Carrizo (20%). This was due to a lower root activity and soil water extraction in the soil profile in trees on Cleopatra compared to trees on Carrizo under well irrigated conditions. This was reflected in higher plant water potential in control trees on Carrizo (-0.49 MPa) compared to Cleopatra (-0.77 MPa). However gas exchange parameters were similar in both rootstocks. Under well irrigated conditions (July-mid September) trees of deficit treatments on Cleopatra and Carrizo rootstocks had lower soil water content in the root zone than their control trees. This was closely correlated with a significant increase in root activity and soil water extraction after water stress in previously stressed trees in Phase I of fruit growth (May-mid June) compared to control trees. The increase in root activity was higher in DI trees on Cleopatra (4.51 and 2.95 μmol CO$_2$ m$^{-2}$ s$^{-1}$ in DI and Control, respectively) than in DI trees on Carrizo (4.94 and 3.52 μmol CO$_2$ m$^{-2}$ s$^{-1}$ in DI and Control, respectively), inducing, in this period, a higher gas exchange activity in DI trees on Cleopatra compared to their Control trees. In Carrizo was not observed this effect. In other hand, under water stress conditions, $\theta_v$ at 0-40 cm soil depth decreased sharply in DI trees on both rootstocks, maintaining during water stress period (75 days), significantly lower $\theta_v$ values (10%) compared to their controls ($\theta_v > 20\%$). In contrast, in the deeper soil layers (80-100 cm) we observed during the stress period, $\theta_v$ values significantly lower in the DI trees on Cleopatra ($\theta_v = 11\%$) compared to DI trees on Carrizo ($\theta_v = 14\%$), indicating deeper water uptake, possibly related with deeper rooting in Cleopatra. Moreover, root activity in DI Carrizo trees decreased more (reaching lower values than their control) and faster compared to DI Cleopatra trees, which always maintained root activity levels higher than their control. A higher root activity and deeper soil water uptake in trees on Cleopatra resulted in a better plant water status (-1.88 MPa vs. -3 MPa in DI Cleopatra and DI Carrizo, respectively) and higher levels of photosynthesis and gas exchange efficiency during water stress period. We conclude that Cleopatra rootstock is more drought tolerant than Carrizo citrange, mainly due to a higher efficiency in the soil profile water uptake and the maintaining of higher root activity under drought conditions.
A survey on the effect of different levels of irrigation features on the qualitative and quantitative varieties of sunflower

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In this research, the effects of different levels of irrigation on the quantitative and qualitative features of sunflower species during the years of 2002 and 2004 have been studied in “The Agricultural Research Station of Khoy”. The test was laid down as split plot in completely random blocks with four alterations. Irrigation, as the major factor in three levels, after 60, 90, and 120 mm of evaporation from class A plate; and the types of sunflowers (Record, golshid, and Armavireski) were accounted on as the secondary factor. The comparison between the average data on these qualities revealed that after 60 and 90 mm of evaporation, the two levels of irrigation produced the utmost seed and oil. However to use water economically, it is recommended to have irrigation after 90 mm of evaporation together with seed-oil function to yield 3792.2 and 1613.4 kg per hectar, respectively. Also it showed that the maximum number of seeds in each tray belonged to the treatment of irrigation after 90 mm of evaporation and the highest weight of one hundred seeds belonged to the irrigation after 60 mm of evaporation. All of these- that’s, the number of seeds in a tray and seed-oil function and also harvest index were advocated to Record type. Of course, the mutual effects of irrigation and the kind of seeds on qualities such as the weight of 100 seeds, and its number in a plate and also the oil function in the level of %5 probability was meaningful. The total results of two years research showed that by using the best way of cultivation (for instance, regulating the distances between the irrigations) and choice of refined race sunflower seeds can have a suitable harvest.

Assessment of microirrigation systems on tomato cultivation

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Iran is located in arid and semi-arid regions where water scarcity is the main issue for agricultural production. Herein, using precise irrigation methods and or deficit irrigation management, is an approach to increase water productivity (WP). In this regards, research was conducted for two years to evaluate the use of microirrigation systems in tomato cultivation at Varamin, Iran. The research was based on split plot and randomized block design. The main plots were surface drip irrigation (DI), Drip-Tape irrigation (DTI) and sub-surface drip-Tape irrigation (SDTI) systems. The sub-plots included 3 levels of water consumption; 50, 75 and 100% of crop water requirement based on class A pan-evaporation. According to the results, the maximum yield belong to 100% irrigation level in SDTI. However, there was no significant difference in yield of 100% and 75% irrigation levels. The WP of 75% irrigation level DI treatment was significantly higher compared to other irrigation levels in both DTI and SDTI treatment. The WP of SDTI-75% were in the second level. Economic analysis of the research using partial budgeting method showed that only surface DI 75% had no substitute from an economic point of view, in other words this treatment was the most economical under experimental conditions and therefore is recommended.
P 2.84 - Effects of different irrigation intervals on growth of lime (Citrus aurantifolia L.) seedlings

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This study was conducted in the field for a period of 9 months to study the effects of water deficit and waterlogging on the growth of lime (Citrus aurantifolia L.) seedlings and to estimate the optimal irrigation interval that enhances their growth. Four-monthold seedlings were irrigated daily, every 5, 10 and 15 days with a fixed input of water. The number of leaves and branches were not affected by the irrigation interval, while significant differences were detected between the waterlogged (irrigated daily) and drought-stressed (irrigated every 15 days) seedlings on one hand and the non-stressed (irrigated every 5 and 10 days) treatments on the other hand. The differences were reflected in the rate of increase of stem diameter, plant height, leaf area index and total dry weight.

P2.85 - Aerobic rice: deficit irrigation

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The looming global water crisis makes it more urgent than ever to promulgate water-saving cropping systems, especially for such a water-consuming staple crop as rice (Oryza sativa L.). Since rice is not an aquatic plant, flooding the fields is not necessary. A well-targeted deficit irrigation can supply enough water to produce almost as much grain as under flooded conditions though saving up to 65 % water compared with flooding. In a 2-years field trial in the southernmost Swiss canton Ticino, we grew the high yielding, early-maturing Italian rice cultivar ‘Loto’ under four intermittent irrigation regimes (either spray bar or drip system) on fluvial silt loam soil. During rainfall, a self-moving plastic shelter automatically covered the plots to exclude precipitation from the field. The highest yield, 8.3 t ha⁻¹, was obtained with 545 mm water supplied by spray bar at a dose of 15 mm every other day; fertilisation: 100 kg N ha⁻¹, 50 kg P ha⁻¹, 240 kg K ha⁻¹, 25 kg Mg ha⁻¹. Despite its widely acknowledged drought sensitivity, rice appeared to withstand unharmed medium-level drought (soil matric potential down to -80 kPa at 20 cm soil depth), provided a sufficient nutrient and a minimum, regular water supply. As to more severe drought (soil matric potential below -80 kPa in both 10 and 20 cm soil depth), it mainly delayed the plant development, causing the flowering stage to miss the meteorologically most suitable period, which resulted in spikelet sterility and yield loss.
P 2.86 - Site-specific crop production and precision phenotyping for water limited areas

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Drought and nitrogen deficiencies represent major constraints to plant growth worldwide. For an improved adaptation of plants to marginal environments limiting soil conditions and plants subjected to stresses should be better characterised. Existing methods of soil and plant analysis however are costly and time consuming in delivering information on the actual and spatially resolved site-specific soil properties as well as the biomass, water and nutritional status of crops. Non-destructive techniques to sense soil and plant properties could contribute to improvements. In this paper new developments and applications of non-destructive techniques to sense soil and plant properties are presented. Spatially resolved soil information can be gained by electromagnetic induction, near infrared spectroscopy and by correlating remotely sensed plant stands to soil properties. With such methods soil texture and plant available water in the soil can be characterised. Derivation of relevant soil properties by non-contacting sensor techniques is highly effective and will provide a long-term information for optimised management. Aerial remote sensing and proximal remote sensing allow to determine plant biomass and the water and nutritional status of plants. The methods tested and further developed included aerial and ground-based reflectance based measurements and tractor based laser induced chlorophyll measurements. Together such methods should allow for optimised management to better adapt plants to marginal environments (Site-specific Crop Production) and for a more efficient screening of cultivars subjected to stresses (Precision Phenotyping). We calculated the root water uptake which is essential to optimise rice irrigation.

P 2.87 - Impact of hydrodynamic modelling and optimal scheduling on simulated crop water production functions

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For water resource planning and management, crop water production functions play an important role in both production decisions and policy analysis. Mostly, crop water production functions are computed by using scheduling algorithms on the base of water balance models. However, modelling deficit irrigation requires a reliable simulation of soil water transport into the root zone in order to estimate an accurate crop water response. In addition, the quality of scheduling has an impact on the relationship between the applied water and crop yield. For investigating the impact of both physically based modelling and optimal scheduling on the calculation of crop water production function, a new scheduling strategy is compared with dynamic programming on the base of water balance models. The new methodology combines evolutionary algorithms, artificial neural networks and rigorous process modelling for substantially improving irrigation efficiency. A physically based hydrodynamic irrigation model is iteratively coupled with a 2D subsurface flow model for simulating the field water balance during a growing period of corn in furrow irrigation. Global optimisation with an evolutionary algorithm finds the schedule with maximum crop yield for a given water volume. The results presented in this paper demonstrate that the new strategy achieves a considerably higher production of corn and thus yields a different crop water production function compared to the dynamic programming.
P 2.88 - Variation in agronomic attributes between old and modern Mexican hybrids of maize in water and nitrogen unfavourable environments

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Field work was conducted to study the response of modern (MH) and old (OH) hybrids, and a variety of landraces (L) under irrigation (I) and drought (D) conditions with two levels of nitrogen (160 kg N ha⁻¹ and 80 kg N ha⁻¹). Drought decreased grain yield (GY), final biomass (FBM), grains per ear row (GPER) and individual grain weight (IGW) by 24%, 18%, 7% and 6%, and plant height (PH), and length (CL) and diameter of cob (CD) by and 51 cm, and 0.5 and 0.2 cm, respectively. Low nitrogen reduced FBM by 6% and PH by 11 cm. Silking date and anthesis-silking interval were delayed by two days (24 ºCd) under drought. MH had greater GY than OH and L in average of drought and nitrogen treatments. GY (r = 0.70, P < 0.05) and FBM (r = 0.68, P < 0.05) were positive and significantly correlated with year of hybrid release in average of drought and nitrogen treatments, and genotypes (excluding L genetic materials); a gain of 57 kg ha⁻¹ year⁻¹ for grain yield and 128 kg ha⁻¹ year⁻¹ for biomass was determined. On the other hand, anthesis-silking interval was negative and significantly associated with year of hybrid release (r = -0.76, P < 0.05). This study reveals that a greater biomass and a shorter anthesis-silking interval may be the key issues to improve grain yield of maize for water and nitrogen limited environments.

P 2.89 - The effect of tillage systems on the phenology and metabolism of carbohydrate on winter wheat

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No tillage systems help reduce soil erosion, yet crop growth is often adversely affected by the presence of surface residue. A field study was conducted on a silty clay loam during 2003 to examine the growth and development of three winter wheats grown under conventional (fall plow and spring disc) and no tillage (direct drilling) tillage systems. Throughout the growing season, leaf and tiller production, tiller abortion, and soil moisture were monitored while leaf area, leaf weight, and stem weight were determined at weekly intervals in 2003. The length of second leaf on main stem, rate of leaf production, and rate of tiller production were reduced in plants grown in no tillage compared with conventional tillage. Also tiller production was reduced by no tillage but tiller abortion was not. Total non-structural carbohydrates in the lower stem - crown area at 12 days after anthesis were not affected by tillage treatment overall these results indicated that stresses that occur early in seedling development under no tillage reduced early growth and the plants were unable to overcome these effects prior to maturity. However, cultivars differed in tolerance to these early stresses. thus, it should be possible to develop winter wheat cultivars for growth under no tillage.
**P 2.90 - Effect of deficit irrigation on water use efficiency of potato grown under every-other furrow irrigation**

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The every-other furrow irrigation is one of the methods of deficit irrigation in furrow irrigation system. In this research, a randomized complete block design with three irrigation treatments and four replications on potato was established in the Agricultural Research Center, Shahrekord, Iran. The irrigation treatments were: 1) ordinary furrow irrigation, 2) fixed every-other furrow irrigation, and 3) alternative every-other furrow irrigation. The frequency of irrigation was constant and the depth of it was calculated by the measurement of soil moisture deficit, and the volume of irrigation water was measured by a counter. The water quality was normal. The different fertilizers were used. The initial soil salinity was 0.19 ds/m. After harvesting, yields were weighed and the water use efficiency was calculated for each plot. There was a significant difference between water use efficiency under different treatments, so that the second treatment had the most water use efficiency.

**P 2.91 - Evaluation of drought tolerance in Iranian landrace wheat genotypes by using stress susceptibility and tolerance indices**

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Iranian landrace wheat genotypes’ responses to stress were evaluated in the present study. Experiments were conducted during the 2002-2003 season at the research farm of Seed Improvement Research Institute in Karaj, with applying full and deficit irrigation for 90 Iranian landrace wheat genotypes. Trials were designed as alfa-lattice with two replications and each replication contained 18 sub-main blocks and 90 plots. Results showed that differences among genotypes were statistically significant (p < 0.01). Therefore, landrace wheat genotypes had different response to stress. In this study, stress tolerance index (STI), susceptibility index (SSI), geometric mean (GMP), mathematical mean (MP) and stress tolerance (TOL) were estimated based upon grain yield for landraces under stress and non-stress conditions. Wheat genotypes were selected based on mentioned and estimated indices, with grain yield of 5,286 and 4,344 kg/ha in the non-stress and stress conditions, respectively. Selected genotypes had STI, SSI, GMP and MP of 1.42, 0.68, 4,792 and 4,815 kg/ha, respectively. Relationship between grain yield and indices and corresponding correlation coefficients were estimated, and STI, GMP and MP were positively correlated with grain yield in both stress and non-stress conditions. Therefore, mentioned indices could be applied for identifying wheat genotypes with tolerant to drought properties. The tested wheat genotypes were classified for grain yield and indices as four groups with cluster analysis.
P 2.92 - Chickpea (Cicer arietinum L.) ideotypes for drought areas in the Mediterranean region

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Cultivated chickpea, Cicer arietinum L., is traditionally sown in the spring period in the Mediterranean region. The crop suffers from drought and high temperature stresses in the spring period especially in late sowing. To overcome drought stress, chickpea could be sown as (i) a winter crop with cold tolerant and ascochyta blight resistant chickpeas, and as (ii) a spring crop with drought tolerant chickpeas. In this communication, two chickpea ideotypes were recognised for drought conditions in the Mediterranean region: (i) the first has a deep and a dense root, at least double pods per node, increased branches and 100-seed weight, resistant to ascochyta blight, yield stable, early seedling vigour and very early types in order to escape drought stress; (ii) the second ideotype can be grown as a winter crop up to 1000 m altitude. This is large or medium seed size, at least double pods per node, increased branches, resistant to ascochyta blight and fusarium wilt, and highly cold tolerant in order to tolerate cold in the target environment. Our collection, including annual wild types, had been screened for drought and cold tolerance. Crossing works and mutation breeding techniques both in cultigen and annual wild types have been initiated for ideotype chickpea selection.

P 2.93 - Screening for drought tolerance in chickpea (Cicer arietinum L.)

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Drought is the most important yield restricting factor in chickpea (Cicer arietinum L.). Drought resistance can be achieved by drought escape and drought tolerance in crop plants. Drought escape usually consists of earliness to avoid the onset of severe water deficits in plants. A total of 40 test lines and one susceptible check (ILC 3279) were screened for drought tolerance using a 1-9 visual scale, where 1 is free from drought effects (Very Highly Tolerant) and 9 is zero seed yield (Very Highly Susceptible). The susceptible check was repeated every two test lines. Genotypes were grown in travertine soil as spring sowing after 2 months than normal sowing time in the coastal region of the west Mediterranean of Turkey for two years (2003-2004 growing seasons). After the susceptible check, ILC 3279, was scored 9 since the check was affected by drought with no pod setting; test genotypes were evaluated for drought tolerance. Drought tolerance score of genotypes ranged from highly tolerant (FLIP 00-44C) to very highly susceptible (ILC 3279 and FLIP 98-206C). Genotypes were also assessed for seedling vigor, days to flowering, days to maturity, plant height, the first pod height, biological yield, seed yield, harvest index and 100-seed weight. The drought tolerance score was significantly and negatively correlated with seed yield, biological yield, harvest index, pods per plant, plant height and 100-seed weight; while it is significantly and positively related with seedling vigor, days to flowering and maturity. Results suggested that earliness and seedling vigor were the most important drought tolerance parameters in chickpea. The screening method described here was useful to screen many germplasms and to select drought tolerant chickpeas in a short time.
P 2.94 - Drought research on sorghum in Mali: breeding for drought prone environments

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The climate of Mali is characterized by high inter- and intra-seasonal variation of amount and duration of rainfall. More than 500,000 ha are under drought conditions where sorghum yield loss varies from 30 to 100%. These environments are characterized by erratic rainfall resulting in drought stress during crop development. For a better screening of varieties in drought resistance studies, the Malian sorghum improvement program breeding has focused on sorghum improved adaptation to drought environments. Appropriate and effective testing environments (400-800 mm) where soil moisture stress naturally occurs under the low rainfall conditions of Mali are used for drought research. These areas are characterized by the quantity of rain in pre-rainy, rainy, post-rainy and dry seasons. Adaptive responses to drought differ genetically for differing types of drought stress. Therefore, no single target drought environment easily identified, no single drought response/tolerance will suffice to provide necessary adaptation. Breeding for adapted and vigorous sorghum varieties has been our approach to breed sorghum with adaptation to these drought prone environments. Most of the local sorghums possess range of adaptive characteristics providing fitness over vagaries of environments. The use of local germplasm in the breeding program is one of the bases of this approach. Photoperiodism, an adaptation characteristic to seasonal phenomenon has been used for its synchronization of flowering at the end of the rainy season. Certain local materials with several other adaptive traits (non senescence, stalk lodging resistance, effective rooting, etc.) enable stability over drought were explored. Large field screening nurseries are utilized at several locations with different stress environments, different planting dates (Bema, Same and Cinzana) of identifying superior genotypes. Farmer participation in evaluating breeding materials has resulted in a better comprehension and appreciation of on adaptation/associated traits that will able breeders to focus on helpful traits that are required in breeding for drought prone environments.

P 2.95 - Yield components of upland rice lines with different numbers of drought QTLs in water-limited conditions


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The main constraint for upland rice production is drought. The development of drought resistance and increasing yield in upland rice for high land areas is a crucial goal of the rice breeding programs. Such a program will have considerable impact not only in increasing upland rice productivity but will also contribute to changing the breeding practices of the minority ethnic groups in the highlands as a result of the permanent cultivation. In this poster, we present the preliminary results on the field testing of upland rice lines having different numbers of QTLs in the water-limited highland areas. The results obtained showed that there was significant variation in yield components of the tested lines at the favorable and water-limited conditions. The yield of the parents and most of the lines was greatly reduced under water-limited condition. However, there were four lines which gave an even higher yield. The correlations between the total QTL numbers and each yield component were not observed. However, the total QTL numbers were correlated with the total yield in water-limited condition.
P 2.96 - AGRIDEMA: an EU-funded effort to promote the use of climate and crop simulation models in agricultural decision-making

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Climate change assessments concluded that extreme events, such as flooding and drought, will be more frequent in the near future. Particularly, the combination of higher temperatures and lesser rainfall-water availability could become a serious climate risk to Mediterranean agriculture. Negative climate impacts could be reduced significantly by running available crop-growth simulation models combined with seasonal weather forecasts. Decision-makers could use the simulation results to choose the most effective actions. However, local agricultural researchers, who are usually involved in decision-making support, are not very aware about these simulation techniques. According to this, a Specific Support Action called AGRIDEMA was recently funded by the EU in order to establish connections and feedback mechanisms between high level research centres and Universities; where modelling tools have been developed and tested (“developers”); with their potential users from local agricultural decision-making (“users”). It will be done through initial contacts, short courses and pilot primary assessments. The pilot assessments to be funded with AGRIDEMA should be addressed to local important issues as, for instance, reducing drought impacts on crop production through an effective water management, as obtained from the climate and crop simulation results. AGRIDEMA aims to establish a continuous acting information network, comprising several European “developers” and “users”. The details and timetable of the AGRIDEMA proposal are outlined here, as well as ways to be incorporated into AGRIDEMA activities for those who might be interested.

P 2.97 - Preparation and application of a novel inorganic-organic hybrid superabsorbent nanocomposite

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Superabsorbents are widely used in agriculture and horticulture. Recently, research on the use of superabsorbents as water managing materials for the renewal of arid and desert environments has attracted great attention, and encouraging results have been observed, as they can reduce irrigation water consumption, improve fertilizer retention in soil, lower the death rate of plants, and increase plant growth rate. Organo-attapulgite was obtained by modifying attapulgite with quaternary ammonium compound (such as hexadecyltrimethyl ammonium bromide). A novel inorganic-organic hybrid superabsorbent nanocomposite was synthesized by grafting acrylamide onto organo-attapulgite micropowder. Thermal stability and water absorbency of the synthesized nanocomposite was improved greatly after the organization of attapulgite. The effects of this superabsorbent nanocomposite on soil physical properties indicate that soil water content, pH value, > 0.25 mm aggregates, porosity and cation exchange capacity were increased greatly, comparing with the superabsorbent composite doped with natural attapulgite.
P 2.98 - Water-saving and anti-drought combined technological measures’ influences on maize yield formation factors and water utilization efficiency in semi-arid region of China

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Adopting the split sections design method, the influences of water-saving and anti-drought combined technological measures (bed-irrigating sowing, seedling stage mending irrigation, and ridge plotted field water conservation) on maize yield formation factors and water utilization efficiency (WUE) in semi-arid region in China was studied. Through the intensive studies on the dry matter accumulation status, on changes to leaf area, to LAD, to net assimilation rate, to yields and to WUE under different technological measures, the relations between maize yield and the amount of limited water supply and ridge plotted field were obtained, and through the optimisation analysis, the regress equations of maize yields under the conditions with and without ridge plotted field were established respectively, and the extent of the water amount for bed-irrigating and mending irrigation were proposed in the paper.

P 2.99 - Evaluations of drought on yield and yield components of Azarghol (Helianthus annuus L.) in different density

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Sunflower is one of the most important oil-seeds in the world. It has some special attributes, one of which is relative tolerance to drought stress. It also has high quality oil. Drought stress is one of the most important factors that decrease crop yields. This is the main limiting factor in development of cultivation and increasing yield in Iran. Sunflower yield is highly affected by plant density. An experiment was conducted on Azarghol hybrid cultivar to evaluate drought stress effect in different densities. RCBD based split plot design in four replicates and four drought period levels (control, beginning drought from tenth leaf appearing, flower bud and pollination), four plant densities (45, 60, 75 and 90 thousand plants ha) were used. Drought applied at 40% field capacity. Results showed that drought decreased plant height, stem and anthodium diameter, seed number in anthodium, 1,000 kernel weight, plant yield, total yield, full and empty seeds number, total dry matter, harvest index, stomata number in leaf apical and lower surface, oil percent and yield. Drought had no significant effect on full seed percent, empty seed percent, grain weight, testa weight, stomata length and width in leaf upper and lower surface. Increasing density from 45,000 to 90,000 plants/ha led to significant decrease in plant height, stem and anthodium diameter, seed number in anthodium, 1,000 kernel weight, plant yield, total yield, full and empty seeds number, grain weight, testa weight, seed length and width, leaf, stem, anthodium and total dry matter, oil percent and yield. Desired density for highest harvest index decreased by increasing drought level. Highest yield (6,477 kg/ha) was obtained in 75,000 plants/ha in control. Increasing periods of drought from tenth leaf to pollination period led to 4459, 4878 and 5256 kg/ha in 90,000 plants/ha, respectively. Trend of oil was like as in yield trend.
P 2.100 - Effect of organic and inorganic nitrogen fertilizer on wheat plant under water regime

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A field experiments were conducted during two successive seasons to study the effect of soil moisture regime (M1, M2 and M3) 80%, 60% and 40% of available soil moisture (ASM) respectively. Two source of organic fertilizer (chicken manure and sun flower residue) and three level of nitrogen on wheat plant. Data revealed that increasing or decreasing the available soil moisture at the root zone resulted in a significant decrease on yield of grain and straw. Application of irrigation at 60% (ASM) resulted in the highest yield in all the years. The interaction between irrigation and fertilization significantly increased in grain and straw yield as compared with the control. Adding N fertilizer at rate 40kgN/fed with chicken manure and sun flower residue gave increase in N and K content and uptake in both soil water regime. Data also, indicated the high level of moisture (M1) with fertilizer gave high increase in P content and uptake as compared with M2 and M3. Application organic matter with nitrogen levels gave increase in N, P and K content and uptake as compared with adding organic matter alone. Organic composts improved bulk density, total porosity, macro and micro pores, soil water retention and soil hydraulic conductivity compared with untreated soil. On the other hand, water use efficiency (WUE) of wheat plants was much better under organic composts at M2 than M1 and M3 treatments.

P 2.101 - Influence of water stress on emergence of Fusarium verticillioides from corn plant tissues

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The fungus Fusarium verticillioides may exist in plants of corn (Zea mays) in either a disease producing or a symptomless, endophytic association. Drought stress has been implicated in field studies as the stimulus for the outbreak of F. verticillioides disease symptoms in corn. The purpose of the current studies was to analyze the regulation of F. verticillioides distribution in corn plants grown under controlled environmental conditions in growth chambers. Drought stress was imposed on plants at three different ages of 1, 2 and 3 weeks after planting. Kernels of corn were artificially infected with a pathogenic strain of F. verticillioides, transformed with the plasmid carrying genes for the expression of β-glucuronidase and hygromycin resistance. Control and drought-stressed plants were grown from F. verticillioides PATg-inoculated seed. All plants were analyzed at 4, 6 and 7 weeks after planting for growth, visible disease symptoms, and distribution of F. verticillioides in plants. At seven week after planting, growth was significantly reduced in all three drought stress treatment groups, but no disease symptoms were visible. In spite of the absence of disease expression, F. verticillioides PATg was isolated from all drought-stressed plants as well as the control plants. The fungus was more common in above ground parts of the plant in the control plants than the water stressed plants. Visible disease symptoms associated with classic stem rot were induced in drought stressed plants of all treatment groups by applying water to exceed maximum soil water holding capacity at seven weeks after planting.
P 2.102 - Improving water use productivity in sugar beet through deficit irrigation

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Water is the most important factor which limited agriculture in Iran and its optimum consumption is necessary. Sugar beet is one of the most important industrial crops, which at now about 180,000 ha are cultivating under this crop. Due to the high water requirement of sugar beet, optimum irrigation management of this crop with deficit irrigation techniques is a suitable solution for increasing water use productivity (WUP) in dry areas such as Iran. Recently, Drip-Tape irrigation systems have been developed for row crop production. In this paper, to achieving controlled deficit irrigation by using Drip - Tape irrigation systems, the effect of four irrigation frequency (1, 3, 4 and 5 days) on four growth stages (Settling, Development, Swelling and Ripening) of Sugar beet have been studied. The experimental design was randomized block arrangement with three replicates. The applied water for conventional treatment (one-day irrigation frequency) was 100% of complete water requirement and for the other treatments was equal 69-94% of complete water requirement. Results indicated that with decreasing applied water the amount of sugar increased from 17.1 to 20.5%. Maximum Root yields (51.24 ton/ha) was belonging to conventional treatment (one-day irrigation frequency and complete water requirement). However, maximum water use productivity determined in 80% complete water requirement treatment which was 1.01 kg/m³.

P 2.103 - Effects of irrigation disruption and sowing date on yield and essential oil of Dill (Anethum graveolens L.)

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Field and greenhouse experiments were carried out in order to determine the effects of irrigation disruption and sowing date on yield and essential oil of Dill (Anethum graveolens L.) at the agricultural station of Salmas in Northwest of Iran. Treatments of greenhouse experiment were 20, 40, 60, 80 and 100% of soil available water. In field experiment four treatments were used: I₁ = irrigation was skipped during stem elongation, I₂ = irrigation was skipped during umbel appearance, I₃ = irrigation was skipped during grain filling period, and I₄ = plots were irrigated in all growing stages (control). These treatments were studied on three sowing dates (April 3, 18, and May 4) in a factorial experiment. The results indicated that WUE for dry matter production decreased, while WUE for essential oil production was not affected by the amount of soil available water in greenhouse. It was concluded from the field study that for higher grain and essential oil production, and for efficiently use of water, dill must be sown early in the spring (April 3 to 18) in Salmas. Water deficit during stem elongation and umbel appearance reduced grain yield, WUE in producing dry matter and essential oil, but irrigation disruption during grain filling period had no significant effect on WUE and grain yield of dill.
P 2.104 - Development of water-saving agriculture in the west semi-arid region of Heilongjiang province

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The semi-arid region in Heilongjiang province is one of the main grain production bases in China. In the region, the rainfall distribution is not uniform during the year, and the 80% of rainfall is concentrated in summer season. Dry spring threaten the agricultural production seriously. According to the nature conditions and the water resources characteristics, taking some technologies such as spray irrigation, drop irrigation and spot irrigation, protecting cannel from seepage, two sets of integrated technologies which are suitable for sloping and plain cultivated land respectively are established, which would be benefit to water utilization efficiency promoting and sustainable development of agriculture in the region.
P 3.01 - Path analysis of grain yield, its components, and some morphological characters in spring wheat under normal and drought stress conditions

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To study the correlation between a grain yield and its components and some morphological characters in spring wheat, 24 lines coming up from landrace, two landraces Yazlegh 1 and 2 and four improved varieties were evaluated. This experiment was conducted at the research station of Faculty of Agriculture, Islamic Azad Shabestar University in 1997, using a Rectangular Lattice Design 5*6 with two replications in normal and drought stress conditions. In this experiment 17 traits were studied. Results showed significant difference between genotypes in most traits in both conditions, that shows significant genetics differences between studied genotypes. In the evaluation of 1000 kernel weight with positive and high effects on the grain yield and with the high correlation with grain yield were known as the components in increasing grain yield under normal conditions. The plant height, number of kernels in spike and the percentage of ground cover traits in the growth period noted the most changes of 1000 kernel weight. Under stressed conditions, number of kernel per spike, flag leaf area and percent ground cover traits in the period of growth with direct effects 0.914, 0.374, 0.388 determined grain yield, respectively.

P 3.02 - Effect of deficit irrigation on potato varieties, under sprinkler irrigation method

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This study was conducted to determine the effects of deficit irrigation and water stress in sprinkler irrigation system on yield, quantity and quality aspects of potato varieties. This experiment was conducted in a randomized complete block with split block arrangement in three replications in 1998-2000 at Esfahan Research Station in Freidan of Iran. The main plots were three different amounts of irrigation water (100, 75 and 50%) of crop water requirement and water stress in the first stage of growth, and the subplots were two potato varieties (Cosima and Moren). The amount of evaporation from class A pan, uniformity of irrigation system, water distribution, emergence percentage, number of stems, flowering date, canopy and the other factors were measured. Experimental results showed that there was no significant difference between yield of potato varieties, multi-interaction and years. The effects of irrigation treatment on yield were significant at p = 0.01. The yield of complete irrigation treatment (30 t/ha) showed best result and the yield of irrigation treatment with 50% of irrigation water (18.7 t/ha) showed less result. Water stress treatment in first stage of growth with 27.2 t/ha and 4.8 kg/m³, showed the highest water use efficiency. Thus, during water scarcity, water stress treatment in the first stage of potato growth can be used to save the water.
P 3.03 - Optimal levels for some characteristics in Brassica oilseed crops in drought conditions

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The breeding programs are rarely based on single characters. When selecting for various traits simultaneously, a correlation between them may restrict the response to selection. The problem is that, which characteristics and where attention should be directed for the greatest prospect of breeding gain in the drought condition. Studying some important crop characteristics in a population and consideration of the limitations and facilities, is a reliable way to select the suitable genotypes. In this way, a part of population is used as a standard for evaluation of other parts and an optimal level is defined for each characteristic. In order to determine the optimal levels of some characteristics in Brassica oilseed crops in the cold drylands of Iran, a broad information bank was collected using results of 4-year trials on Brassica oilseed crops in the cold region and was studied through boundary lines method. Optimal levels of some crop characteristics including days to flowering, days to physiological maturity, duration of grain filling, number of pods per plant, number of seeds per pod, plant height and thousand kernel weight were determined as, 77.7 days, 122.8 days, 43.8 days, 111.5, 17.3, 92.2 cm and 1.79 gm, respectively. These data were closely related to optimal levels in averaging method.

P 3.04 - Study on stability of selected lines of safflower under dryland conditions in Iran

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Safflower can increase the sustainability of farming systems by acting as a disease break in rainfed area that is mainly devoted to cereals. Twenty-five promising lines of safflower were evaluated under rainfed conditions in thirteen environments in Iran. Statistical analysis was conducted using residual maximum likelihood (REML) procedure on grain yield. There was significant variation in grain yields within both lines and environments. Interaction between genotype-environment was highly significant (P < 0.01). The study showed that linear function is a major part of the genotype environment interaction. Seven genotypes showed average stability with the grain yield above the grand mean, indicating that they have general adaptability. In contrast, six entries had regression coefficients significantly greater than 1.0 and produced mean grain yields above the grand mean, which were sensitive to changes in the environments and are adapted to favorable environments. Eight entries had regression coefficients significantly less than 1.0, with grain yield below the grand mean. Amongst them, two genotypes had the lowest CV and could be recommended only for cultivation in unfavorable conditions.
P 3.05 - Drought tolerance study in common bean

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To study drought tolerance indices, 10 common bean varieties were evaluated in a split plot experiment in the form of complete block design with three replications. The main plots were three environmental conditions, namely: non-stress (normal), drought stress at vegetative stage and drought stress reproductive stages. On the basis of seed yield, five indices, i.e. mean productivity (MP), geometric mean productivity (GMP), tolerance (TOL), stress susceptibility index (SSI) and stress tolerance index (STI) were evaluated. Stress intensity was equal to 0.12 and 0.55 for stress at vegetative and reproductive stages, respectively. The indices STI, MP and GMP were highly correlated with seed yield of normal (y_p) and stress (y_s) conditions. With the index STI, tolerant and high yielding cultivars could be distinguished. Using a 3-D plot, cultivars were grouped into A-D groups. In the vegetative stage stress conditions, cultivars Emerson 74, Dehghan, Jules and Sayyad were located in group A, cultivars Daneshkadeh and Talash in group B and C, respectively, and cultivars 11805, Naz, Akhtar and Cos-16 in group D. In the stress condition at the reproductive stage, cultivars were located as: Emerson 74, Dehghan, Jules and Daneshkadeh (group A), Sayyad (group B), Akhtar and Talash (group C) and Naz and Cos-16 (group D).

P 3.06 - Impact of technology adoption on drought proofing in rainfed rice ecosystems of Tamil Nadu, India

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Data drawn from secondary sources and farm household survey (365 farm households) conducted in the rainfed rice tracts of Tamil Nadu, India were analysed to comprehend the technology adoption by farmers to mitigate drought impact. The study identifies the yield gap due to drought, technology adoption lag and combination of both. Ploughing to fine tilth, direct line sowing with higher seed rate, seed treatment using Azospirillum and Bavistin, integrated nutrient and weed management at critical stages are the common drought proofing technologies taken up by farmers. Technology Adoption Index (TAI) is constructed to catalog farmers' technology adoption in rainfed districts viz., Coimbatore, Thiruvallur, Sivagangai, and Ramnad. More than 50 per cent of farmers in Coimbatore and Thiruvallur districts are moderate adopters; whereas in Ramnad and Sivagangai, over two-third of the farmers are laggards and are engrossed in traditional technologies. Gini coefficients are derived to find any divergence among the adoption categories. Though in Ramnad there is no variation in technology adoption among farm categories, significant difference is observed in Coimbatore and Thiruvallur districts. Shift in production function, estimated through test of covariance, is attributed to integrated nutrient management and drought proofing technologies. The study findings call for adoption of improved varieties and other superior technologies such as integrated weed management, modern methods of sowing. Farmers relied mainly on land races, albeit its poor yield, as they are tolerant to drought stress. In this context, agricultural research should streamline innovative technologies to incorporate vital traits from land races and strengthen the agricultural extension system to disseminate all drought proofing technologies.
P 3.07 - Effect of drought stress on quantitative and qualitative characteristics of oil seed rape (Brassica napus L.)

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To evaluate the effects of water stress on quantitative and qualitative characteristics of six rapeseed (Brassica napus L.) cultivars were investigated. The crops were grown under three limited irrigation (50, 100 and 150 millimeter evaporation from evaporation basin class A ) as a main factor and cultivars (Colvert, Regent, Cobra, Slm 046, Fornax, okapi, orient) as a subplot replicated four times. The experiment was conducted in karaj seed and plant improvement institute - oil seeds research department in 2002. Comparison of means for seed yield, plant height, branch number per plant, pod length, pod number per plant, pod number per main stem, seed 1000 weight, harvest index, seed number per pod, seed oil percent and glucozinate showed significant differences among cultivars. Result didn't show significant differences for seed number per pod, biological yield, seed oil percent and glucozinate among water treatments, but other characters showed significant differences. The effect of water stress on TDW, NAR, RGR, CGR and LAI were significant. With increasing of water stress, the amount of Glucozinate in seeds decreased but it was not statisticly significant. cv. Okapi showed higher and cv Fornax lower amount of glucozinate.

P3.08 - Drought stress effects on quantitative and qualitative characters of commercial sunflower cultivars and hybrids

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In order to study the effects of water deficit stress at different reproductive stages on quantitative and qualitative characters of commercial sunflower cultivars a filed experiment was conducted in karaj seed and plant improvement institute - oil seeds research department in 2000. Experiment was done as a split plot design based on randomized complete block design with three replications. Three levels of stress 1 control irrigation was done after 60 mm evaporation from class A evaporation pan drought stress at budding stage irrigation was done after 200 mm evaporation from class A evaporation pan and reirrigated similar to control 3 drought stress at grain filling period irrigation was done after 200 mm evaporation from class A evaporation pan and reirrigated similar to control were placed in the main plot and cultivars were placed in the sub-plot at four levels. Cultivars were consist of 2 open pollination cultivars namely record and armavirsky and 2 commercial hyrids namely golshid and hysun 33. Results showed that water stress treatments no irrigation at any stage reduced seed yield and to decreasing of yield componets such as seed number and seed weight. Head diameter, harvest index, oil percent, oil yield and growth indices also were reduced by them. Record cultivar had the highest seed yield, water two treatments. Oil percent, TDM and LAI generally open pollination cultivars, Record and Armavirsky at all traits together with tolerance indices were superior than hybrids.
P 3.09 - Evaluation of physiological and agronomic characters of oilseed rape cultivars for late season drought tolerance

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Water deficit is an important factor limiting crop production worldwide. Flowering and grain filing stages of oilseed rape in most cropping situations coincide with dry period. In order to increase oilseed rape production especially in semi-arid regions, identification of drought tolerant cultivars is considered important. Many reports have indicated that water deficit by decreasing the relative water content and increasing leaf temperature could decrease photosynthesis and ultimately yield in oilseed rape. The purposes of this study were identification of late season drought tolerant cultivars and evaluation physiological and agronomical characters of those cultivars, under drought stress. The experiments were done in agricultural research and natural resources center of East Azarbaijan (46º 2' E, 37º 58' N), Iran, during 2001-2003. The study was based on factorial design with two factors including drought stress (Late season stress and non-stress) and five oilseed rape genotypes, in three replications. The results showed that relative water content and leaf temperature are efficient indices for recognizing the effects of water deficit on oilseed rape plants and screening drought tolerant genotypes. Water deficit decreased oil and yield mainly by decreasing the siliqua numbers per plant. The stress did not have significant effect on the meal glucosinolate amount. It seems that providing sufficient water to oilseed rape plants during flowering and seed filing stages is more important for producing higher yield. The results revealed that Okapi and SLM-046 in comparison with Talayeh, Regent-Cobra and Fornax had the higher seed and oil yield and also showed the lesser decrease in seed and oil yield under drought stress. Therefore these two genotypes can be used in areas with late season drought stress.

P 3.10 - Long-term weather analysis and simulation of durum wheat yield in dryland area of Southern Italy

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Recent studies have shown that the climate of the planet is changing. Increasing carbon dioxide emission (CO₂) in the atmosphere is one of the causes responsible for increases in temperature. If the weather is really changing, how do temperature and CO₂ changes affect wheat production? The objectives of this study were a) to analyze a long term record of weather data (1952-2003) provided by the Agronomic Research Institute (Bari) that included daily minimum and maximum temperature, precipitation, and solar radiation; b) to evaluate the effects of climate change on the Duilio cultivar of durum wheat for the period 1975-2003; c) to validate the CERES-Wheat model using the long term weather and yield data; d) to perform a sensitivity analysis on the effect of different CO₂ concentrations in the atmosphere on durum wheat yield. A statistical analysis was performed on the weather data, assessing standard deviation and coefficient of variation of each month of the year for the 53 years of available weather. The measured yield data were provided by the Ministry of Agriculture. The yield varied from 1.5 to 6.4 t ha⁻¹, with a mean value of 3.9 t ha⁻¹. A poor correlation was found between seasonal rainfall and yield, demonstrating that water was not always the limiting factor. A similar relationship was also found by Passioura (2002) for Australian wheat yield. Increases in the simulated ratio ET/PET with yield showed that low values of ET/PET are indicators of low yield. The CERES-Wheat model performed well when compared with the 29 years of measured data. The model was able to correctly simulate the trends of low and high yield that occurred during those years. The sensitivity analysis using different CO₂ levels showed that the CERES-Wheat model accounts for CO₂ increase as shown by the increases in yield with increasing CO₂ levels.
P 3.11 - Genetic male sterility as a tool to develop drought tolerant populations of barley

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Genetic male sterility in barley (Hordeum vulgare L.) was first reported by Suneson in 1940 with the suggestion that it could be utilized as a tool in the production of hybrid barley. Also, genetic male sterile genes are used to eliminate hand emasculations in plant breeding programs and thus to facilitate the development of recurrent selection populations in normally self pollinated crops. One of the most important attributes of male sterility in a population is to provide for maximum recombination with a minimum of effort and could be utilized to the maximum by harvesting separately, seed set on the male sterile plants. By employing this approach, drought tolerant populations may be developed efficiently with the premise that only more turgid (drought tolerant) plants would engage in outcrossing. In our program, several plants with sterile florets characterised by open glumas were identified in the M2 populations of Kaya and Quantum varieties of barley of which the seed were treated by 150 and 300 Gy of gamma-rays. The inheritance and the cross-pollination characteristics of these gamma-rays male sterility sources were investigated in semi dry conditions. It was found that the gms sources are recessively inherited and stabl over the environments and no negative pleiotropic effects on fitness characters. The aims of this communication are to provide data on outcrossing frequency on genetic male sterile plants in semi-dry conditions, discuss the role of genetic male sterility as a tool to select more turgid plants which are better adapted to drought conditions and outline an MSFRS strategy to develop drought tolerant populations of barley.

P 3.12 - New cropping systems in semi-arid Mediterranean environments: potential role of medicinal and aromatic plants

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The semi-arid Mediterranean environments represent somehow “fragile” ecosystems, whose correct management needs some special attention. It is crucial therefore to study and point out some innovative farming systems able to deal with an income for workers, but in the meantime environmentally friendly and requiring the minimum energetic and technical inputs. In such sense, the cultivation of some selected medicinal and aromatic plants (MAPs) could be an important strategy. In our work we made an attempt to sketch a comprehensive evaluation of the input levels required by 23 selected herbaceous MAPs, taking into consideration the indicative average levels of the energetic (including manpower) and technological inputs required by each of them.
Mediterranean is one of the most fragile and vulnerable ecosystems of the world because of prolonged drought periods and erratic patterns of rainfall. It then urges to define environmental indicators which have to be considered not only as instruments for assessing desertification but also for monitoring impact of prevention and mitigation programmes. The assessment of desertification risk at regional scale requires modelling spatial variability of environmental variables. Traditional approach, based on estimating point environmental indicators, cannot be considered satisfactory for this purpose, because it does not take into account spatial dependence between variables. This paper presents a new approach to the problem, in which two global risk indices are estimated and mapped using multivariate geostatistics and GIS. The proposed approach is based on a simple binary transformation whereby each datum is transformed into an indicator, before variography and kriging. By convention, data are coded as 0s or 1s, if they lie above or below given threshold values, which have to be calibrated locally. Each individual indicator is then mapped as the probability that the corresponding environmental variable is beyond (or below) the threshold value, so that the area can be rated according to the desertification risk in relation to that parameter. A synthesis evaluation of the desertification risk can be done by weighting and summing the different indicators performing a spatial Principal Component Analysis through factor kriging. The proposed method is quite flexible and allows to take into consideration a variable number of individual indicators, for each of which a critical threshold value has to be defined. This contribution is an example of application to the meteorological dataset of Apulia Region (south-east Italy), which is considered representative of the Mediterranean zones at high risk of desertification. Three meteorological variables were selected: minimum and maximum of air temperature and rainfall. The maps of the first two regionalised factors allowed to delineate the areas of Apulia region at high risk of desertification where specific management practices or land use policies should be developed. This approach could be used as operational support to a wide range of activities, not only for estimating, assessing and mapping the extent of desertification but also for determining the causes, quantifying the impacts, justifying the reclamation costs and monitoring the efficiency of the measures taken.
P 3.14 - Effect of reducing irrigation on biomass production and aesthetic quality of Festuca arundinacea turf

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In turf management, sustainability issues involve considering irrigation as a critical cultural practice, as in many areas it affects a limited renewable resource. Irrigation may also induce high biomass production, involving economic and environmental costs for mowing and disposal of grass clippings. In central Italy, Viterbo (42°25'N, 12°4'E), five irrigation levels were applied to a Festuca arundinacea cv. Rebel turf from June 2001 to November 2002. Treatments were equal to 100, 75, 50, 25 and 0% of ETm (maximum evapotranspiration) calculated multiplying pET (potential evapotranspiration) by crop coefficient (0.8). Plots were mowed at a height of 6 cm if higher than 8 cm. Nitrogen fertilization rate was 130 kg ha⁻¹. No pest and disease control was conducted. Total biomass production and growth rate were measured each time turf was mowed. Aesthetic appearance of turfgrass plots were rated on a monthly basis. Treatments at 100, 75 and 50% were strongly different from 25 and 0% both for biomass production. Small or not significant differences were found among 100, 75 and 50% treatments. Aesthetic quality and biomass production were strongly correlated during summer months. This study showed that irrigation levels lower than ETm allow to limit water consumption while maintaining the same technical characteristics and promoting an healthy growth of tall fescue turf. Replenishment of 75 and 50% ETm could be alternated, applying the lower irrigation rates if no stress is occurring. Disposal costs of grass clippings can not be reduced by reducing irrigation without affecting turfgrass quality. Sustainability of human activities assumed an ever greater importance during the last years. Turfgrass production has been affected by this process by a critical reviewing of its cultural practices. Specifically, in addition to agrochemical consumption, irrigation needs are one of the most important issues related to turf as they affect a limited renewable resource. Irrigation has always been considered among the most important activities in turf management both for agronomic and environmental implications. Excess irrigation may cause turfgrass yellowing, diseases spreading and nutrient runoff, while insufficient irrigation produces turfgrass withering, thinning out or permanent damage. Budget or water availability limitations and ecological attention by public administrators are further reasons for which irrigation management has to encourage turfgrass growth and in the meantime to avoid water waste. Festuca arundinacea Schreb. appears to be one of the most promising species for saving water. Replenishment of 75 and 50% ETm could be alternated, applying lower irrigation rates if no stress is occurring, while using higher rates in order to help tall fescue turf to withstand stress periods.

P 3.15 - Drought resistance evaluation in cotton and path analysis of its effective characters

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Drought is the most important limitation factor in agricultural productions of the world. For this reason, investigation on various aspects of drought on species and the nature of resistance to the stress is of much importance. In this research, ten varieties of cotton (Gossypium hirsutum L.) were studied in two separate randomized complete block design (RCBD) field experiments each with four replications to assess their drought resistance. One of the experiments was irrigated and the other one not. Yield was significantly different (at 5% level) between the studied varieties in irrigated experiment. The varieties didn’t show a significant difference in non-irrigated experiment. In pooled analysis, varieties showed a significantly different yield (at 5% level). Yield changes in the two experiments were estimated. Yield change was remarkable which is due to polygenic nature of the character and the significant effects of environment on the character. Phenotypic correlation between all combinations of pair characters were estimated. The correlation of most of the studied characters to yield was negligible. This would imply the difficulties of the cotton breeding through a single character for yield improvement in drought stress condition. Furthermore, the correlation between the yield in the two environments was also negligible. This would also imply the difficulties of yield improvement in irrigated experiments for high yield performance in dry condition. Regarding path analysis, stem base diameter, which is easily measurable, can be used as a suitable selection index for yield improvement, drought tolerance and suitable yield in dry environments.
P 3.16 - Evaluation of drought resistance of tetraploid cotton cultivars at different osmotic levels

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Drought is the most important limitation factor in agricultural productions of the world. Average rainfall in Iran is 240 mm for which the country is included in arid to semi-arid areas. For this reason, investigation on various aspects of drought on species and the nature of resistance to the stress is of much importance. In this experiment to evaluate osmotic resistance of cotton, determined in the laboratory in three replication with factorial experiment as completely randomized design (CRD). The first factor was 20 cultivar tetraploid cotton and the second factor was 4 osmotic levels (0, -8, -16, -24 bar) results showed that cultivars of giza with 0.972 and crema with 0.942% have the most rate of seedlings and these are the most tolerant cultivars to drought stress. The results of this research indicates that cultivar sahel with 0.006 gr higher drought weight of rootlet among the cultivars. Also, results showed that cultivar saiokra had more growth and drought weight of stemlet among the cultivars.

P 3.17 - Evaluation of sunflower hybrids, CMS and restorer lines to drought stress

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The objective of this study was to evaluation of 24 sunflower hybrids, three A-lines and eight Rf restorers to drought stress. Genotypes were arranged in two simple lattices design (6 x 6). In the first experiment treatments were irrigated as normal condition (60 mm evaporation from pan, class A) and the second, they were irrigated as stress condition (180 mm evaporation from pan, Class A). Phenologic, morphologic, agronomic characteristics were recorded under normal and stress condition for all genotypes. Combined analyses of variance showed that CMS-19xR-217 in normal and drought condition had the highest yield that set as a same groups with four hybrids. It had high seed per head and seed weight. Head diameter of genotypes were declined by stress, but stress declined hybrids and CMS lines heads more. Oil seed content were descended in stress condition., but there were no significant differences in oil seed content for R-217 and R254 at normal and drought conditions. Stress tolerance and susceptibility indices were used to select drought tolerant genotypes. “CMS-19 and R-217” were superior among inbred lines, and CMS-19xR-217 produced the highest yield that were in the same group with three hybrids by Duncan’s test. Evaluation of genotypes by SSI index showed that “CMS-19 and R-254” had the lowest susceptibility to stress and CMS-19xR-217” were the most resistant genotypes to drought. Therefore, CMS-19, R-217 had superior characteristics among inbred lines and CMS-19xR-217 the best among the hybrids.
P 3.18 - Study of drought stress effects on yield and some agronomic and physiological characteristics in rapeseed

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In order to investigate the effect of drought stress on yield and some agronomic and physiological characteristics in rapeseed (Brassica napus L.), a field experiment was conducted as split-plot arranged in a Randomized Complete Block Design with four replications in 2002/03 in Karaj, Iran (at: 35°59’ Northern and 50°75’ Eastern). There were two factors: Irrigation at two levels (80% of evaporation as control, and drought stress started from stem elongation stage) as main plots, cultivars were: Sarigol, Goliath, Heros, Comet, Amica, Sw5001, Crackerjack, Eagle, Wildcat, Swhotshot as sub factors. Biological yield, grain yield, harvest index, grain weight, oil percent, number of lateral branches, number of pod in main branch, total pod, pod length and proline percent were measured. Results showed that irrigation levels had no significant effects on biological yield, grain yield, harvest Index, grain weight and oil percent among cultivars. Amica c.v. had maximum number of pod (180.1), pod length (6.6) and pod in main branch (49.9). Additionally, the most proline content belonged to Eagle (0.23%) that had significant difference in comparison with other cultivars (P < 0.01). Interaction effect of irrigation levels and cultivars showed that maximum pod length (6.7 cm) and number of lateral branches (6.2) produced by Amica c.v. in drought stress. But Comet c.v. had the most number of pod (192.7), and also maximum proline content obtained in Heros and Eagle in this condition. However, Amica with 4233 kg/ha had the best grain yield under normal irrigation, and Heros and Comet cultivars (with 3830 and 3620 kg/ha, respectively) compared to other cultivars had maximum grain yield under drought stress without significant difference.

P 3.19 - Correlation and path coefficient analysis of yield and agronomic traits in wheat under late water deficit conditions

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One hundred bread wheat varieties, advanced breeding lines and landraces were studied in field trials under water deficit and non-deficit (near optimal) conditions over four years. Water stress during stem elongation and grain filling was provided each year by erecting a rain-out shelter at the tillering phase. Average yield reduction due to the drought treatment in sheltered plots was 37.8%. On a genotype mean basis, grain yield under late drought was significantly positively correlated with fertile spikelet number/spike, grain number/spike, grain number/spikelet, 1000 grain weight, biomass/plant, harvest index, production/spike and spike index. Grain yield under late drought conditions was highly negatively associated with sterile spikelet number/spike and tiller number/plant, followed by plant height and heading date. Spike length, spike number/m² and flag leaf area had no significant effects on yield. Path coefficient analysis (PCA) was used to determine direct and indirect sources of correlations, using genotypic correlations of plant attributes. Although in both stress and non-stress conditions production per spike showed the highest positive genetic correlation with grain yield, PCA revealed a somewhat different result. Harvest index (0.837***) and biomass/plant (0.697***) had the highest direct effects on grain yield under late water deficit, while production per spike had no significant direct effect (0.096). However, PCA confirmed that production/spike (2.244***) was the most important component of grain yield in near optimal conditions. These results imply that different selection criteria would be appropriate for developing high yielding genotypes under late drought and near optimal conditions.
P 3.20 - Application of image analysis to quantify drought related effects in medium and high throughput screening of plants

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Effects of drought on plants are strongly related to the time of reduced water availability. The plant responses may depend at least on genotypes and environmental conditions. This makes higher numbers of replicates and reproducible measurements highly important to differentiate between significant biological effects e.g. related to specific genes or external influences including “biological variability”. The presentation shows options and tools to quantify growth of plants over the whole life cycle by image processing. The whole process can be automated to allow screening of high numbers of plants in time under different stress conditions without destruction. Depending on the plant species information on leaf area, plant size, leaf number, leaf colour, morphology and architecture are provided. In specific kind of test system used additional information on root growth can be provided. As all measurements are quantitative and stored in a database system advanced statistics and averaging can be used in subsequent data analysis. The datasets are a major step forward to make whole plant screening quantitative. Use of appropriate transformation of raw measurement data into biologically relevant parameters are discussed with special regard to growth measurements.

P 3.21 - Biotechnological approaches for improvement of plant productivity and yield under arid soils of Uzbekistan

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Uzbekistan is an agroindustrial country, in which the desert occupy more than 60% of all republic’s territory, and only 10% (4.3 million ha) of total territory is taken up for agricultural lands. Because of inappropriate application of mineral fertilisers in crop production has resulted in pollution and salinization of agricultural lands and water resources also led to ecological catastrophe – drying of the Aral Sea. With respect to agriculture, there are two main consequences of the crisis affecting agricultural production in the region: desertification of soils with excessive salinity and decreased fertility of over-intensively cultivated soils followed by increased salinity. Drought and salinity are the main stress processes of desertification, which strongly influence and break processing of many biological processes in living soil organisms. Such areas require intervention of biotechnology, improving not only the crop (creation of high yield variety) but also soil productivity and health and the interactions of roots with its soil microorganisms. The creation of association stress tolerant strains (resistant to drought, salinity, etc.) of microorganisms under different agricultural crops can lead to increase plant productivity and soil fertility of poor and salt affected soils. Beneficial microorganisms help improve plant growth, nutrition, responses to external stress factors, and root growth pattern under arid conditions too. The aim of the research work was to create bacterial fertilisers, optimal composition of rhizosphere microorganisms, resistant to drought and high temperature conditions, and study their effect on yield of cotton, wheat and maize in arid salinated soils of Uzbekistan. Bacterial inoculants increased plant growth and yield of crops in arid soils and play an essential role in helping plants establish in such conditions. The challenge is how to make use of these inoculants in the agriculture of Uzbekistan. Creation of such bacterial fertilizers will hopefully help improving cropping methods in arid lands, and help sustainable development by ensuring long term soil improvement.
P 3.22 - Use of infrared thermometry for developing baseline equations for main crops of Thrace Region in Turkey

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Productivity response to water stress is different for each crop and this response is expected to vary with the climate. Therefore, the critical values of crop water stress index (CWSI) should be determined for a particular crop in different climates and soils to use in yield prediction and irrigation management. Predicting yield response to crop water stress is important in developing strategies and decision-making for the use by farmers and their advisors, and researchers for irrigation management under limited water conditions. A range of empirical studies have shown that there may be different non-water stress baselines which can be used to quantify CWSI for evaluating plant water stress and that ideally these need to be determined for each agro climatic zone in which the crop is being grown. This research reports on field experiments carried out to develop baseline equations in five different traditional crops (wheat, sunflower, watermelon, potato and bean) in Trakya Region, Turkey. The CWSI was determined by using the empirical approach for the all crops and the yields were directly correlated with the mean CWSI values and it can be used for the yield prediction. The results showed that CWSI values may also provide a valuable tool for monitoring water status and improving irrigation scheduling for all crops.

P 3.23 - Present and future options for commercial farmers in drought-prone environments

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This presentation takes the perspective of the modern commercial farmer in drought-prone environments. It focuses on dryland farming, where actual evapotranspiration (ET) falls well below potential ET, and where herbaceous vegetation dominates. Thus the views refer to farming systems with annual field crops, predominately wheat, coarse grains, pulses and some oilseeds in the world’s semi-arid and sub-humid regions. Such farming is characterised by its relatively large scale, mechanization, and high indebtedness in the face of historically low global real grain prices. To survive, the ultimate test of sustainability, farmers must manage wisely, and be prepared for bad luck in the form of drought, namely those years when rain is well below average. Choice of cropping season is largely fixed by climate and soil, but there is often considerable scope to gain by considering crop species, water supply to the crop, and the efficiency with which it is converted into grain, and to profit. Decisions, balanced against their cost, can and must be made: to maximize rain water storage and retention in the crop root zone; guarantee crop establishment at the optimum time and subsequent root exploration of the wet profile; minimize weed competition; and balance crop growth against expected water supply through manipulation of crop variety, sowing date, density, and row spacing, and N supply. These decisions are dominated by expectations of average rainfall, but can trade yield against risk reduction. The latter is a widespread consideration, also practiced through diversification of enterprises (e.g. combining animals and crops), and of crops and varieties, through fallowing, and via various financial instruments (e.g. insurance). Forecasts, especially seasonal forecasts, can be factor in some of this decision making, particularly when drought is predicted, but forecast skill is still too low to help much in most places. Overall much progress has been made in the past, both on the breeding and the agronomic fronts, but in the future, competitive pressures will continue to increase. Various factors dictate the enduring comparative advantage of these dry areas for world grain production (apart from rice) but the scale of operation will continue to increase, and operator skill must also grow; coping with drought will be a big factor in this culling of farmers. Reduced tillage, precision farming, better seasonal forecasts, alternative crops and rotations, and better varieties could yield further efficiency gains, at the same time as greater consumer attention to quality and climate change begin to challenge planning. The paper will seek throughout to highlight opportunities for crop genetic improvement.
P 3.24 - Improvement of drought resistant wheat varieties in Uzbekistan

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Sustainable crop production is the basic approach for agriculture in the 21st century. After independence, big changes occurred in the cropping systems of Uzbekistan. They are associated with both development of food security policy of the independent state and transition to market economy. The population growth rate in Uzbekistan (2.4% per year) will reach around 35 million (presently 23-24 million) by 2010. This will sharply raise the demand in foodstuffs that requires significantly increasing the production of agricultural crops under arid conditions. Wheat is the key grain crop for Uzbekistan. Most of the arable area of the country suffers from elevated salinity to a various degree. The area of saline irrigated lands in Uzbekistan amounted to 1.97 million ha, including low-saline lands - 1.12 million ha, medium-saline - 0.611 million ha, strong-saline - 0.24 million ha. For this reason, the annual shortage of grain yield is 500,000 tons. Moreover, soil salinity adversely affects the quality of grain. The solution to this problem in terms of the transition of Uzbekistan to the social-oriented market economy, urgently requires increasing productivity of the grain industry. One of the most essential factors of developing the grain industry is to put into production highly productive grain varieties resistant to diseases, drought and soil salinity, as well as moisture deficits. In such areas choice development and cultivation of high yielding wheat varieties based on scientific research is the most important objectives. Some salinity tolerant varieties has been developed through individual selection. Those varieties have shown to be tolerant to heat and some diseases, as well as to saline soils. New disease-resistant, a drought-resistant, resistant to lodging, high-yielding varieties of wheat for existing soil and climate conditions of the region are being created, studied and applied; the structure of seed production is being developed.

P 3.25 - Use of bio-organic approach to combat desertification and soil salinity with application of 15N technique

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Several greenhouse and field experiments were conducted using the15N labeling technique to evaluate the role of different microorganisms as well as labeled plant residues on enhancement of grown plants under poor fertile desert soils. Nitrogen fixation by asymbiotic bacteria has been observed in greenhouse and field experiments under dry land cropping systems. Biological N2 fixation associated with crop residues (legumes or cereals) was investigated in pot experiments with wheat and chickpea cultivars. In these experiments, both residues of wheat and rice were labelled with 15N and used as organic N sources in comparison with either 15N-labelled ammonium sulfate or ammonium nitrate as chemical nitrogen fertilizers. Dual inoculation with Rhizobium and mycorrhizae fungi significantly affected nodulation and colonization percentages of chickpea cultivars. Rhizobium inoculation extended to be used with wheat gave the best results of growth parameters and N2 fixation when combined with Azospirillum brasilense as heterotrophic diazotrophs. The economical return of Azospirillum brasilense (as liquid media or commercial product) was estimated with maize crop grown under field conditions. The obtained data showed that inoculation combined with the half dose of recommended N fertilizer rates was the most effective and low cost agricultural inputs. The nitrogen uptake by wheat plants was significantly increased by application of soybean residues and inoculation with Azospirillum brasilense. This field trial concluded that soybean residue as enriched N material, and Azospirillum brasilense inoculation enhanced growth, grain and N yields of wheat cultivars grown in poor fertile sandy soil.
How will increased drought conditions modify the yield advantage of intercrops over monocrops? Results from greenhouse experiments

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Intercropping is still an important practice in the tropics. In some cases, intercrops over-yield the monocrops involved. It seems clear that global climate change will intensify drought conditions in some tropical areas. Yet, drought research in intercrops is scant, and little is known about how these changes will modify an intercropping advantage where it exists. Recently, plant ecologists and agro-foresters have studied how inter-specific plant competition and facilitation change along resource gradients. Plant ecologists have also explored how species richness and composition affect over-yielding in multispecies natural plant communities. It seems necessary and possible to integrate these studies, and to extend them to relevant agroecosystems subject to increased drought conditions. With this purpose, we have developed at ECOSUR a series of greenhouse experiments. Two will be briefly presented. The first comprises a 160 micro-plot experiment that compares and explains the drought response of eight monocrops vs. the drought response of the eight possible combinations of these crops in seven-species polycultures. The second experiment comprises a 350 micro-plot study that evaluates the drought response of wheat and chickpea monocrops (each at five different densities) and their 25 substitutive intercrop combinations. Experiment 1 shows a significant effect of drought on the relations between species richness/composition, inter-specific competition and productivity. Experiment 2 shows that almost all 25 intercrops over-yielded in moist soil. Over-yielding was reduced by drought but persisted in many cases. Intercrops with higher over-yielding in moist soil had a more than proportional capacity to maintain this over-yielding condition in drier soil.

Irrigation water productivity in the arid environment of the Senegal River basin: rice and sorghum

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In the 1970s, Mauritania developed irrigated perimeters next to the Senegal River and compelled rice production in order to increase food security. Decades later, the irrigated land has declined or been abandoned due to misconception and/or mismanagement. New efforts, based on perimeter rehabilitation, improved management and crop diversification, are trying to re-launch irrigated agriculture. This participatory study analyzes the potential of irrigated sorghum, otherwise a traditional crop grown after flood recession, as an alternative crop to rice monoculture. Six representing plots/farms were selected in the Bélinabé, farmers-managed, small irrigation perimeter. Farmers cultivated their plots (3 with sorghum and 3 with rice) following local (rice) or researchers’ (sorghum) recommendations. Water balance, crop development and production, culinary quality and economic balance were determined. Sorghum yield varied largely among farms (0.00, 0.78 and 2.52 t/ha), as expected being cultivated for the first time in these conditions. One plot was abandoned due to heavy rains and poor establishment. The second plot had large waterlogged sections due to water intrusion from the secondary canal. The third plot did not have any major problem although yield components indicated sink limitations. Sorghum yield varied largely among farms (0.00, 0.78 and 2.52 t/ha), as expected being cultivated for the first time in these conditions. One plot was abandoned due to heavy rains and poor establishment. The second plot had large waterlogged sections due to water intrusion from the secondary canal. The third plot did not have any major problem although yield components indicated sink limitations. Rice plots yielded 6.24, 5.94 and 3.71 t/ha. Comparing the best rice and sorghum plots, water productivity was 0.55 and 0.44 kg grain/m³, respectively, whereas, in terms of economic benefit, it was 12.4 and 63.4 €/m³, respectively. Thus, sorghum comes along as a profitable alternative to rice, particularly in the lighter soils and when water availability is limited, provided the crop is well managed and water-logging is avoided.
As stomata close, energy dissipation is decreased and leaf temperatures rise. Investigating the relative contribution of stomatal conductance, meteorology, and canopy architecture to canopy temperature can aid development of thermal imaging as a reliable method of remotely determining drought stress in field crops. We monitored the temperatures of leaves and canopies of field grown grapevines, subjected to different irrigation regimes, in the dry Alentejo region of southern Portugal during the summers of 2003 and 2004. Thermal images showed significantly higher temperatures of canopies in non-irrigated compared to fully irrigated vines, indicating greater stress (lower conductance) in the non-irrigated plants. Moreover, canopies receiving regulated deficit irrigation had significantly higher temperatures in August, when irrigation of these plants was reduced, than canopies receiving deficit irrigation or partial rootzone drying. Canopy temperatures were significantly negatively correlated with stomatal conductance, measured with a steady state porometer. In 2004, when images were taken of individual leaves rather than canopies, temperature did not differ significantly between treatments and was not correlated with stomatal conductance. This influence of leaf angle may be greater for individual leaves than canopies. No correlation was found, however, between leaf orientation or inclination angle and measured temperature. Additionally, drooping of leaves during wilting did not significantly affect canopy temperatures. Model calculations with meteorological and stomatal conductance data were used to simulate the leaf temperatures at different angles.

We studied the influence of summer drought and winter temperatures on seasonal and spatial variations of light-saturated net photosynthesis and stomatal conductance in Mediterranean woody species. We measured variations in leaf mass area and gas exchange over three years in 13 Mediterranean trees and shrubs, located at four different sites along a climate gradient of temperature and precipitation in the island of Mallorca (West Mediterranean basin). Net photosynthesis and stomatal conductance were at a maximum during spring, autumn or winter and at a minimum during summer in most sites, species and years. Nevertheless, important spatial, temporal and species-specific variations were observed. Summer drought limitation to gas exchange was greatest in the dry part of the transect, where many species showed their maximum gas exchange rate during winter. In contrast, winter temperatures limited gas exchange of many species at the wet and cool end of the transect, while summer depression of gas exchange was shorter and less pronounced. Semi-deciduous species showed greater net photosynthesis than evergreen sclerophyllous species when integrated over the years. Their net photosynthesis also varied more, suggesting that they are more sensitive to seasonal changes of water availability, probably as a consequence of their shallow root system. These results suggest that the effect on carbon fixation and productivity by the predicted increase of aridity in the Mediterranean basin will depend on whether gas exchange is mostly limited by summer drought or by low winter temperatures.
**P 3.30 - Advances and prospects of crop drought resistance**

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Drought is one of the most common environmental stress. In China, especially in northern China, drought is the most serious limiting factor for agricultural production. Research on drought resistance mechanisms have been a hot spot for many years, and various kinds of morphological and physiological indexes for drought resistance have been put forward, but so far the study on drought resistance mechanisms is not in-depth, and the indices put forward are not perfect in practice. We summarized the mechanism research of drought resistance of both China and abroad. More developments had been obtained on the aspects of conformation and physiology and molecules briefly discussed and analysed the breeding thinking and direction we had confidences to drought resistance breeding. We think it is a horspot that we improve the crop drought resistance and clarify matter basis and physiological function of crop drought resistance on the molecular level, then recombine drought resistance genes and create new drought resistant types by using genetic engineering, and we can confirm the drought resistant indexes by using expressing form of the kind genes. Drought resistant breeding has a wide developing.

**P 3.31 - Relationship of water use efficiency with biophysical and yield parameters under various moisture regimes in cotton (Gossypium sp.)**

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It is essential to identify cotton genotypes, with higher photosynthetic rates having higher water use efficiency (WUE) under moisture stress conditions. With this in view, 52 cotton genotypes belonging to G. hirsutum, G. herbaceum and G. arboreum were screened under five moisture regimes. G. arboreum genotypes had more WUE with increase in moisture deficit conditions. Among the genotypes, DB-3-12, LRA-5166, DDhc-11, AK-235 and Jayadhar had more WUE at higher moisture stress. The positive relationship of water use efficiency with yield (r = 0.5) indicates the importance of WUE under moisture stress conditions. The rate of photosynthesis, conductance and transpiration decreased with an increase in moisture stress. However, the percent reduction varied among the species. The percent reduction in photosynthesis from M1 to M5 moisture regimes was least in G. arboreum (28.1%) as compared with 30.2 and 30.4% in G. hirsutum and G. herbaceum genotypes, respectively. Irrespective of the species, the genotype LRA-5166 had maintained significantly higher photosynthetic rates under moisture stress conditions. The genotypes, which showed optimum photosynthesis, had less transpiration rates under moisture stress conditions. Genotypes, LRA-5166, DB-3-12 and AK-235 which were found to be drought tolerant possessed lower transpiration rates of 4.59, 3.59 and 2.99 as against the susceptible genotypes Abadhita, Kumta and Virnar-79 which possessed 5.14, 3.65 and 5.24 mmol H₂O m⁻² sec⁻¹, respectively, in each species. Thus, the tolerant genotypes possessed moderate photosynthesis and lower transpiration rates, which resulted in lower canopy transpiration, higher WUE and yield under moisture stress conditions.
**P 3.32 - Grain yield heterosis and drought tolerance in the inter-ecotype hybrids between P/TGMS lines (irrigated rice) and upland rice or aerobic rice varieties (O. sativa L.)**


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Eighty inter-ecotype hybrids (inc. 40 *Indica*/ *Indica*, 32 *Japonica*/ *Japonica* and 8 *Indica* (wide compatible line)/ *Japonica* combinations) between 9 photoperiod/ temperature-dependent male sterile (P/TGMS, irrigated rice) lines and 16 upland (or aerobic) rice varieties together with their fertile parents and CK (commercial hybrid cultivars) were tested in a well irrigated field and a site with artificially induced drought stress during reproductive and grain filling stages. Both agronomic traits and drought related traits were recorded during the growth. And 10 plants per replicate in each experiment were harvested at maturity for measuring the grain yield and yield components. Grain yield heterosis was prevailing in the inter-ecotype hybrids. Average heterobeltiosis of the *Indica*/ *Indica* combinations were 35.7% (-91.2 to 156.0%) and 118.2% (-96.2 to 1308.1%), while that of the *Japonica*/ *Japonica* and *Indica*/ *Japonica* hybrids were 40.1% (-42.9 to 295.9%) and 136.9% (-100 to 1,272.3%) in irrigated and drought stressed environment respectively. 58 inter-ecotype hybrids had higher yield in well irrigated field and 32 got higher yield over their upland (aerobic) parents in drought stressed field. Greater variation in heterobeltiosis was resulted by the different response of experiment materials to drought stress: complete yield loss of a hybrid resulted in -100% and low yield of a fertile parent lead to 1,272.3%. 21 and 16 *Indica* inter-ecotype hybrids yielded more than a commercial *Indica* hybrid cultivar Eryou725, 27 and 33 *Japonica*/ *Japonica* and *Indica*/ *Japonica* hybrids had higher grain yield than a *Japonica* hybrid cultivar Ejingzal in well irrigated and drought stressed fields respectively. Inter-ecotype hybrids such as 1103s/IRGA318-11-6-9-2B (*Indica*/ *Indica*), 3516s/Zhonghan5 (*Japonica*/ *Japonica*), PA64s/Huhan3 (*Indica*/ *Japonica*) etc., achieved higher yield than their CK in both well irrigated and drought stressed fields.

**P 3.33 - Productive sustainable rice based rotation in saline-sodic lands in Egypt**

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Most of the soils of northern part of the Nile Delta in Egypt are saline-sodic. Farmers are used to growing rice in monocropping systems. Land productivity decreased and water table gradually increased and this cropping pattern has deleterious effects on both cropping (cotton in particular) and soil characteristics. These studies proposed diversifying the rice-based crop rotations to diminish these detrimental effects, conserve fertility and maintain sustainability. The studies comprised comparing different forms of rice-based crop rotations which prevail in the rice belt. The very wet two-year-based rotation (rice every year) which predominates in the whole area were compared with proposed two-year-dry rotation (rice in one year) or three-year-very-dry rotation (one rice every three years). In addition, short duration rice varieties (sakha (1) - 125 day) were grown in the proposed rotation to rationalize irrigation water use instead of the long duration varieties (Reho- 145 days) used in prevailing rotation. The crop phase occupied the main plots in the split plot design was divided in four subplots treated wit: (a) manure (b) gypsum (c) manure and gypsum (d) control. The data revealed that production of the proposed two- or three-year-rotations exceeded that of the prevailing two- or three-year-crop rotations. On other hand, water use consumption of the prevailing two- or three-crop-rotations exceeded the proposed by 12.5 and 28.5%, respectively. Addition gypsum, manure or both increased growth and yields of all crops. The split up dose of gypsum and manure had the most favourable effects. Chemical characteristics of the soil in the proposed rotation improved more than in the prevailing (PH, ESP, EC) under the influence of crop rotation duration in as well as soil treatments. Profitability of rotation was inconsistent and was dependent on crop price fluctuations.
P 3.34 - Delocalisation of irrigated agricultural production to the South Mediterranean: consequences on water use, its efficiency and sustainability

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Water is a rare and expensive resource and, in Mediterranean countries it is needed for agricultural production and the irrigated sector, which uses 80% of the water harnessed. While 40 to 50% of final production comes from irrigated perimeters, it constitutes only 7% (Tunisia) and 13% (Spain) of the agricultural area. However, the use of this water is costly for the environment and in manpower. The choice of crop is not always a rational one in terms of efficiency of production, and a number of problems are linked to the cost of manpower needed to produce it. Southern Europe calls on seasonal illegal workers to achieve this production. Restrictive legislation has limited their use in France. In Spain, this is still widespread and the current legalisation of this workforce is evidence of the importance of this phenomenon. As an answer to these problems of agriculture on the northern side of the Mediterranean, it has already been observed that there is the beginning of delocalisation of agricultural production, along with the use of the local workforce. This takes several forms: production under contract and the setting up of new farms by farmers from the Northern Mediterranean. This solution, while allowing cost reductions for the northern countries, poses the problem of its impact on the use of water resources and the environment of southern countries. This paper will compare the various components of the production price of irrigated crops and present some aspects of the consequences on local agriculture and water resources.

P 3.35 - Drought effects on Tunisian agriculture and its sustainability

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Under Mediterranean conditions, drought is a permanent risk. It has direct effects on agricultural production and also on farmers’ income and on the national economy. A description of Tunisian climatic characteristics and of agricultural production is given to show the impact of rainfall, the extent of the variation in production of the main rainfed crops, cereals and olive oil, and also the long term consequences on fruit trees and on livestock. Adding to the reduction in agricultural production resulting directly from water deficit, drought has other consequences that should be considered. Farming systems have a key role in buffering year to year rainfall variability. However instability of rainfall, production and income have consequences on agricultural practices that are related to risk management with reduced intensification, lower water use efficiency and less agricultural production during rainy years. Examples from cereal production are given. At the national level, drought has a cost and there is a need for other sectors to compensate so as to maintain GDP. National policy should help improve the sustainability of agriculture in semi-arid and arid environments and overcome its short and long term effects. It should allow farmer’s incomes to be maintained and reduce long term consequences of drought.
P 3.36 - BIOTIC: A biologically-based protocol for irrigation scheduling

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Timely and efficient application of water to crops is an essential component of the efficient use of irrigation in agriculture. In regions with sufficient water resources the appropriate use of water will extend supplies and optimize production. In those regions with declining or insufficient water resources irrigation scheduling provides a mechanism for insuring the timely application of water in amounts needed by the crop and by limiting excessive irrigation can extend the water resource over both time and space. The BIOTIC irrigation protocol uses a combination of a species-specific temperature threshold and a region-specific time threshold to schedule irrigation. BIOTIC has been implemented in a variety of crops, in several regions and with drip and sprinkler irrigation systems. In all instances it has been shown to be as effective as soil moisture and ET based irrigation scheduling. A primary advantage of BIOTIC versus other methods is its simplicity in terms of equipment and end user operation. Development of hardware and software for implementation of BIOTIC in production environments has been investigated in conjunction with ag producers in on-farm demonstrations.

P 3.37 - Kernel development and improvement of irrigated winter wheat grain yield under terminal drought stressed conditions in Iran

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Drought stress at the post-anthesis stage causes considerable damage in the wheat growing regions in Iran. The yield and kernel weight of winter wheat were measured at Karaj, Iran in 2003-04 to determine how rate and duration of kernel filling and position of the kernels in the spikelet and along the spikes affects the potential of kernel weights, assimilate supply and yield. Overall rates and duration of kernel phases differed significantly between genotypes. The highest regression slope (bi) for kernel filling rate was observed in Gascogne French cultivar and in C-80-10 a new Iranian line both with large kernel size. Cultivar differences in the weight of kernels in the A and B (basal) positions in the spikelets ranging from 29 to 50 mg indicated that there was genetic variability for this character. Kernel size of the C and D (distal) positions decreased to approximately 77% of the A and B positions. Kernel E was formed only in C-80-10 line. Removing spikelet numbers increased the kernel weight of the remaining kernels by increasing assimilate supply. Kernel weights from the middle third of the spike were greater than those from lower and upper thirds. Grain yield from upper third of the spike contributed significantly less to grain yield than middle and lower thirds of the spikes for all genotypes. It is suggested that selection of genotypes with a relatively high rate of kernel filling and large kernel size may increase wheat production in the regions prone to terminal drought stress in Iran.
**P 3.38 - Combining ability, heterosis and stability of tropical maize inbreds under stress and optimal conditions**

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The major constraints limiting maize production in tropical and subtropical developing countries are drought and low soil N stress. Genetic improvement of maize for stress tolerance is on-going at the International Maize and Wheat Improvement Center (CIMMYT) and inbred lines with tolerance to major abiotic stresses are available. The objectives of this study were to (i) investigate the combining ability of inbreds (ii) estimate heterosis under the different stresses, and (iii) assess stability of grain yield of inbred lines and hybrids. Fifteen inbred lines of tropical and subtropical origins with a range of response to abiotic stresses were crossed in a diallel mating design. The resulting 105 hybrids were evaluated under drought stressed, low nitrogen, and well-watered conditions in three countries in a replicated alpha-lattice design. Measurements for anthesis date, anthesis-silking interval, ears per plant, and grain yield were taken in each environment. General and specific combining abilities effects were estimated following Griffing’s (1956) diallel analysis. Both GCA and SCA mean squares across environments were significant for all the traits. GCA x environment and SCA x environment interaction effects were also significant for all traits. Inbred CML258 had the highest GCA for grain yield under drought stressed conditions and across locations. Inbred lines CML254 had the best GCA for ears per plant across drought stress across locations. The best hybrid across locations was CML258 x CML343 (4.03 t ha⁻¹). Mid parent heterosis for grain yield was highest in the drought stress environments. Inbred line CML341 was the most stable across locations.

**P 3.39 - Agricultural drought: an index based on transpiration deficit**

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Water stress is present when effective transpiration from agricultural crops falls short of the maximum transpiration, derived from atmospheric conditions and from crop leaf expansion. We present here an agricultural drought index based on the computation of daily transpiration deficit and its integration over time. A water balance model is used for computing daily maximum and effective transpiration for a representative crop (e.g. alfalfa). Daily values of the transpiration deficit (i.e. Maximum - Effective Transpiration) for the current year are integrated over time for 30, 60, …, 240 days before present and the values so obtained are compared with ranked transpiration deficits for the same day of year in the local climatic time series (usually over 50 years). The drought index value coincides with the percentile P of the current value computed as P = R/(N+1) where R is the rank of the current year and N is the number of years available in the time series. Percentiles 100 and 0 represent current values respectively higher or lower than any value present in the reference time series. Examples are presented for years 2003 and 2004 in Emilia-Romagna, an agricultural region of northern Italy.
P 3.40 - Study on the effect of drought stress on yield components and agronomic characterizes in ten cultivars of wheat

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In order to determine the response of wheat cultivars in dry-land farming and investigate yield components and agronomic characteristics, ten cultivars of wheat (Triticum aestivum L.) were evaluated in randomized complete block design with three replications under dry-land farming (2003-2004). Dates for each cultivar in sowing were 15 October for first time, 15 November for second time and 15 December for the last time. Result showed that drought conditions shortened duration of growth and development of cultivars. The second time of sowing, obtained the maximum in yield and yield components. In three sowing dates, a decrease in spike per m² and other leaf surface was obtained but in the second time, 1,000 KW was increased. A positive correlation was found between 1,000 KW and spikelets in spike and harvest index (HI) and a negative correlation was found between yield and plant height.

P 3.41 - Selection indices for drought tolerance in bread wheat (Triticum aestivum)

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For assessment of several drought tolerance indices and introducing of better index and also for analyzing of Iranian wheat cultivars under normal and drought stress conditions, we established this design with using of 21 wheat cultivars in research farm of the Agronomy department of Karaj Azad University in October 2003. The design used was RCBD that carried out under two conditions, drought stress and non-stress. Response of cultivars under this situation were different under non-stress conditions, Alamoot-1 variety was the best and Chenab variety had the least grain yield. Under stress conditions, the best and the least varieties were Alamoot-1 and Khazar-1, respectively. Although stress condition affects cultivars and reduce the grain yield, but we observed that some of cultivars had good drought tolerance and high uptake. We used several selection indices (SIs), such as Mean Productivity (MP), Tolerance Index (TOL), Stress Tolerance Index (STI), Harmonic Mean (HM), Geometric Mean Productivity (GMP), Relative Drought Index (RD1) and Stress Susceptibility Index (SSI), to study drought tolerance of cultivars. We found that the best SI for breeding programs are STI, GMP and Harm, because there are the greatest correlation between this SIs and grain yield under stress and non-stress conditions.
P 3.42 - An evaluation of physiological responses for drought tolerance in dual purpose sorghum (Sorghum bicolor (L). Moench)

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Sorghum (Sorghum bicolor (L). Moench) possesses a variety of anatomical, morphological and physiological features that enable it to survive in water limited environments. A greenhouse experiment was conducted in order to evaluate the drought tolerance in ten parents and 24 hybrids of dual purpose sorghum with a water stressed treatment and well watered control. Effects of water deficits on epicuticular wax content, cell membrane stability (measured by poly ethylene glycol (PEG 6000) test), relative water content, chlorophyll content and proline content were evaluated. In addition to this Drought Susceptibility Index (DSI) was estimated. The correlation between the DSI and the physiological traits was also estimated. The results revealed that the DSI was significantly and negatively correlated with epicuticular wax content (r = -0.54** significant at P = 0.01), proline content (r = -0.53**) and relative water content (r = -0.50**). A positive correlation was found between percentage cell injury in the PEG test and DSI (r = 0.49**). From the above experiment, it may be suggested that drought tolerance in sorghum appears to be controlled by the inherent capacity of the plant to produce epicuticular wax content and proline. These two parameters could be used as index for screening large population for drought tolerance and short list progenies for evaluation at field level.

P 3.43 - Physiological evaluation of synthetic wheat for drought resistance

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Synthetic wheats are the result of a cross between two relatives of putative progenitors of wheat, Tritium turgidum and T. taushii, with subsequent chromosome doubling. These synthetics possess a range of positive traits, including resistance to diseases as Karnal Bunt, fusarium head scab, helminthosporium leaf blotch and tolerance to heat, drought, waterlogging and late frost at flowering. They are spring types that are highly crossable to advanced wheat genotypes. Physiological understanding is essential to enhance this process. Physiological traits could be included in a set a selection criteria by plant breeders. The objective of this study was to examine some morpho-physiological characters among wheat synthetic to drought stress and determine the relationship among these characters. Therefore a set of 66 synthetic hexaploids along with four checks were evaluated under irrigated and drought stress conditions during the year 2001-02 and 2002-03. Observations on excised leaf water loss (ELWL), relative water content (RWC), canopy temperature depression (CTD) Membrane thermostability (MTS), days to maturity and grain yield were recorded. Drought resistance for individual synthetic was computed. Among drought tolerant parameters, the canopy temperature depression and days to heading were the characters which can be used for selection of drought tolerant genotypes even in irrigated conditions because of their consistent relationship with other variables under both environments. DRI was also an important trait as it was related to majority of traits and free from intervening effect of other mechanism, namely drought escape.
P 3.44 - Evaluation of late season drought tolerance in advanced barley genotypes

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A set of 25 genotypes of barley were evaluated for morphological characters using randomized complete blocked design in two irrigated and non-irrigated conditions. The studied traits were day to heading, spike length, day to maturity, peduncle length, number of grain per spike, plant height, number of fertile tiller, biological yield, grain yield, harvest index and thousand kernel weight. The results showed that there are positive and significant correlations between grain yield with number of fertile tiller and also with thousand kernel weight, in both irrigated and non-irrigated conditions. The stepwise regression in non-irrigated condition was indicated that 98% of grain yield variation is explained by thousand kernel weight, number of fertile tiller and number of grain per spike, but in irrigated condition 95% of this variation explained by harvest index and day to heading. The results of path analysis indicated that the effect of thousand kernel weight, number of fertile tiller and number of grain per spike on grain yield were more important than other traits. Therefore, traits such as: thousand kernel weight, number of fertile tiller and number of grain per spike could be included as selection index for yield improvement in barley.

P 3.45 - An assessment of the food security in India in a changing environment

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Economy and life of the majority of the population of India are largely related to agriculture. In spite of extended irrigation facilities, agriculture in vast areas is still dependant on monsoons. Vagaries in monsoons associated with global anomalies occasionally lead to extremes, with their impact on all facets of life. India is included in the list of countries having dry lands that are potentially threatened by desertification. Changes in amount and seasonality of rainfall pose serious threat to the food security. Demands in food and water in the country have been tremendously increasing with fast rising population that may stabilise only after 50 years at 50% more the present level. Reliable water is decreasing with degradation, overuse and improper conservation and management. Impact of decreasing water availability in the already dry interior India will be tremendous, as the region consists of rich agricultural land. The existing water disputes are likely to worsen and new ones are likely to arise, leading to social issues and haltering development activities. In this paper changes in water availability and proneness to droughts in different parts of India have been estimated using models ad statistical techniques. Food situation in an altered environment is assessed. Almost all parts of India show proneness to drought, though not seriously vulnerable. Strategy to face the extreme hydrological conditions, especially to cope with drought conditions is a key development issue in India. Suggestions for an appropriate policy have been presented, based on the environmental, social and economic conditions.
P 3.46 - Study of drought tolerance in barley (Hordeum vulgare L.)

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Drought is the main abiotic constraint on crops yield specially cereals in the world. With regard to importance and different uses of barley and also its suitability for cropping in limited regions like dry and saline lands in Iran, it is important for breeders to identify resist/tolerant genotypes and improve barley yield for this areas. This study is conducted to assay some barley lines in drought stress condition and determine the effective characters on yield in stress and non-stress conditions. 58 genotypes were grown in two similar trials in design and other practices except in irrigation or water regime. Results showed that there are high significant differences between genotypes in both condition. Stepwise regression was used to specify the effective characters on yield in both experiments and it excerpted four characters in normal and seven characters in stressed trial that had high and significant effects on yield. Because of difference in these characters number, it seems there are several characteristics that yield is their resultant and if there is water limitation during the growth period, this traits will determine plant yield. Based on results of this study barley yield could improve by selection for high grain weight, early mature, higher stem and much spike and biomass weight genotypes in drought stress condition. Also plants with shorter growing season, more and bigger spikes and high biomass have more grain yield in normal condition. Finally, selecting for high biomass, spike number and its weight in non-stress condition could improve yield for stress-alleviated condition.
How crops and pastures respond to water stress

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The current drought in eastern Australia, and government policy to increase environmental flows in rivers, has highlighted the importance of utilising water as efficiently as possible. With 65% of the Australian dairy industry almost completely reliant on rainfall for forage production, seasonal drought and extremes of temperature, places unique pressures on continuous forage production. Pasture production accounts for up to 35% of variability in farm profit, with species selection and management the major driving factors. In this context, thirty four commonly used dairy forages, are being evaluated for water use efficiency (WUE), in terms of kg DM/ha/mm of water used and how they respond to drought stress with three levels of irrigation (optimal, and increasing water stress). Annual dry matter (DM) yield ranged from 8-31 t/ha, with maize having the highest yield. The perennial grasses, tall fescue, perennial ryegrass, prairie grass and kikuyu had the next highest yield of 27-28 t DM/ha. Depending on the season, WUE of the forages varied significantly from 12 to 37 kg DM/ha/mm. In winter perennial ryegrass had the highest WUE of 37 kg DM/ha/mm, but one of the lowest WUE in the summer of only 15 kg DM/ha/mm. Maize had the highest WUE during the summer of 33 kg DM/ha/mm. The seasonal response to moisture stress differed significantly between species, the loss in yield in summer ranged from a 33% for lucerne to 82% for white clover. The effect of water stress on WUE depended on the species, having no effect on intrinsic WUE of maize and paspalum, however under increased moisture stress white clover fescue and perennial had a lower WUE.
P 3.48 - Development of drought resistant upland rice for the northern region of Vietnam

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Upland rice is the major food crop for about 54 Vietnamese ethnic groups in the upland areas, among them, 50 are practicing shifting cultivation. Because of slash-and-burn with shifting cultivation the land degradation is a serious problem and drought is common in northern and central parts of the country. The main constraint for upland rice production in these areas is the lack of drought resistant and high yield upland rice. Therefore, development of drought resistance and increasing the yield in upland rice for these regions will have considerable impact not only in increasing upland rice productivity but also contribute to the environmental sustainable. In this report, we present the results on the studies towards the development of drought resistant upland rice, including morphological and molecular diversity, molecular mapping and identification of quantitative trait loci (QTLs) associated to drought resistance, and development of PCR markers for marker-assisted selection.

P 3.49 - Simulation of wheat growth and development under drought stress conditions

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Using a model, it is possible to simulate and identify the process of crop production, thus insuring optimal use of resources and more stable production with higher financial benefits. In this research a model was developed based on Oryza2000 (Bouman et al. 2000) and SUCROS (H. van Keulen et al. 1992). The proposed model is capable of simulating the development stages, carbon assimilation, respiration and assimilate partitioning of wheat crop under different soil moisture regimes. The period of simulation starts with crop germination and lasts until the end of the growth period, using daily time steps. The model requires meteorological data and depth and time of irrigation-precipitation as input parameters. Drought stress assessment is applied through its influence on development rate, leaf expansion, acceleration of leaf senescence, leaf rolling and assimilate partitioning. In order to compute related reduction factors as a function of soil water potential, root zone water balance calculations were performed during each time interval. Calibration of the model was performed with existing field data for several spring wheat varieties grown in the region (Ghobadi 1999; Fard 2001; Ghanbari 2003). Model verification was done with the data collected in a field experiment in Agricultural Research Station at Shahid-Chamran University, Ahvaz during the years 2002-2003. Simulation results showed a good agreement between field study and observed data. Comparison of LAI and dry matter simulation with observation showed of $R^2 = 0.90$, RMSD = 298.7 and $R^2 = 0.88$, RMSD = 0.707, respectively.
P 3.50 - Agronomic performance of improved semi-dwarf mutants of barley in a rainfed environment

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The barley breeding program of Akdeniz University is carried out in rain-fed environments and on farms. Although drought is an important problem in the target region, an increase in annual rainfall has been recorded for the last five years. Therefore, breeding for reduced height and lodging resistant has gained importance. Consequently, semi dwarf improved lines available in the program have been evaluated on farmers’ fields at two locations during last 2 years. Improved lines derived from diallel cross between the parents and the barley mutants, which were selected in barley breeding project started in 1984, were used in the study to test their agronomic performance. Kaya and its mutants, M-K-6 (compact spike, dark green), M-K-35 (lax spike, semi dwarf, late heading), M-K-40 (compact spike, dwarf), and Quantum and its mutants, M-Q-80 (compact spike, semi dwarf) and M-Q-73 (compact spike, erect, large grain) were used as parents in breeding program ( Çağırın & Yildirim 1990). The experimental material was grown at Kizilkaya in 2003 and Urkutlu villages in 2004 (Bucak, Burdur, Turkey) in the West Mediterranean region of Turkey. Twenty six genotypes were included in 2003 at Kizilkaya and thirteen of them, selected from these nurseries for agronomic performance, were grown in a randomised complete blocks design at Urtuktul village in 2004. Grain yield, biomass, number of spike, grain/spike, 1000-grain weight, harvest index, days to heading and plant height were recorded in each genotypes. There were statistically differences among genotypes for all traits measured except harvest index in 2004. Genotypes growing on farmers’ fields at Kizilkaya showed higher agronomic performance than at Urkutlu because Kizilkaya received much more rainfall. A genotype derived from the cross between MQ73XMQ80 had the highest values for grain yield, biomass and number of spikes.


P 3.51 - Diversification as drought coping strategy to sustain rainfed ecosystems of Tamil Nadu, India

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The study derived its data from secondary sources and farm household survey (365 farm households) located along the rainfed rice tracts of Tamil Nadu, India. Forced by the weather related uncertainties during the summer season, the farmers were utilizing only 50% of the total cultivated area. However, area under cultivation during the summer season increased with decrease in farm size revealing that small and marginal farmers use intensively the available land for income generation as well as due to crop diversification. Further, farmers’ risk-coping strategies were classified into ex ante and ex post depending upon adoption of strategies to reduce risk or reduce impact of risk after the production shortfall has occurred. Non farm income and labour earnings are the important safety nets employed during the stress years and this has helped to cushion the adverse impact of stress. Risk reduction through crop diversification, varietal diversification, income diversification and change in agronomic practices are the common strategies followed by the farmers to nullify the effect of drought. Adoption of variety diversification strategy by the sample farmers as ex-ante coping mechanism was very minimal and only 13% of sample farmers have grown more than one variety during the Samba season. As ex-post strategy, sample farmers resorted to borrowing from informal sources during the drought period. Borrowing from informal sources was higher among the small (49%) and marginal farmers (23%). Farmers also engaged in non-farm activities to generate income during the drought seasons and only 12% of the farmers engaged in such activities.
P 3.52 - Effect of water regime on growth and yield of various durum wheat varieties

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In this work we have studied the ecophysiological behavior of four durum wheat (Triticum durum Desf.) varieties according to water regime (100 and 50%) of the field capacity. Some parameters linked to the biologic growth (straw height, leaf area), to the plant physiology leaf water potential and water use efficiency and to yield component have been measured. The results showed that water deficit affects differently the biologic growth as well as yield components of the studied varieties. So water use efficiency is variable according to the varieties too. Our results showed also that leaf water potential is correlated with the highest sensitivity to water deficit and a weak efficiency of water use.

P 3.53- Extent of risk and varietal adoption in rainfed rice agriculture in Tamil Nadu, India

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The paper is based on the secondary and farm household survey data (240 farm households). Risk due to drought is reflected in the level of investment made in modern inputs such as fertilizers and pesticides. Nitrogenous fertilizer consumption in the state declined to 4.09 lakh tonnes in the drought period from 4.68 lakh tonnes in the normal period. Similarly, there was a reduction in consumption of phosphate and potash fertilizers during the drought period. Estimated elasticity shows that response to fertilizer inputs declined during the drought period. Decomposition analysis reveals that reduction in yield due to curtailment of input usage accounts for only 3 to 10% and more than 90% of yield reduction is due to water stress. Estimated yield loss due to drought is 1,400 kg/ha in the case of HYVs, while it is 840 kg/ha in the case of land races. Farmers incurred higher cost due to risk and adoption of varieties with less response to technological inputs (based on the actual and optimal cost of cultivation). Econometric results indicate that yield loss due to risk of rainfall failure was higher in the case of HYVs as compared to land races. A 10% increase in risk resulted in 5.4% decline in yield of HYVs, while the decline was 0.2% in the case of land races. It is imperative that the varieties meant for water limiting environment should ensure minimal level of yield during the stress periods to induce the farmers for higher level of adoption of drought tolerant rice varieties.
Towards developing a general model for optimizing partial rootzone drying irrigation (PRD) in differing soil and environmental conditions

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Partial rootzone drying irrigation (PRD) is a technique that exploits natural drought tolerance mechanisms in plants. In PRD water is applied alternately to only one half of a plant’s rootzone. The dry roots will generate drought signals that modify transpiration, growth and resource partitioning. The watered roots provide the plant with sufficient water to maintain water status. Ideally, plants grown under PRD have reduced stomatal conductance and vegetative growth while plant water potential and harvestable yield are maintained. However, this is not always the case, and the causes of the variable success of PRD are not fully understood. It has been suggested that cases where PRD is not successful may be related to one or more of the following variables: root-shoot signaling mechanism, growth pattern of the shoot and root system, soil hydraulic properties and evaporative demand. We describe development of the model based on studies of growth and water use of runner bean (\textit{Phaseolus coccineus} L. ‘Emergo’) and raspberry (\textit{Rubus idaeus} L. ‘Glen Ample’) grown in coir, peat and sand based media. This model will provide a tool to both to improve our understanding in the mechanisms involved in PRD responses and enable this technique to be optimized for application in a wide range of contrasting cropping systems.

Evapotranspiration and crop coefficient of irrigated citrus orchard under semi-arid climate

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The transpiration (T) of an irrigated citrus orchard (Clementine) was measured by the sap flow method throughout a growing season in a Mediterranean area, submitted to semi-arid climate. Since the measurements took place on several selected branches of the citrus trees, a statistical analysis for determining the “mean tree” has been carried out before the set up of the sap gauges. The daily T measured by the sap flow method has been compared with the evapotranspiration (E) measured by the eddy covariance method, with very good results. The citrus crop coefficient (Kc), experimentally found, is not constant during the growth season, in contrast to the hypothesis presented in the rapport FAO no. 56. From a practical point of view, a model of E is more suitable for simulating correctly the daily path of the actual evapotranspiration. So, a model of the citrus E using a Penman-Monteith–type model is presented, where the canopy surface resistance, supposed variable, is determined from standard microclimatic variables. The calibration coefficients of the proposed model depend only on the crop and they have general validity with respect to the site. The model’s performance was evaluated by comparison with the sap flow data. The results were satisfactory and therefore this simple model allows determination the E of a Clementine Orchard grown under a Mediterranean climate.
P 3.56 - The effects of different moisture on agronomic characteristics of eight soybean (Glycine max L.) cultivars in Shahre-kord location

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Eight soybean cultivars including: Zane, Woodworth, Clark, Steel, A3935, Maccal, Hercor and Lindavon were evaluated under well water and moisture stress (irrigation after 140 mm evaporation from class A evaporation pan) conditions for grain yield potentials and some other related traits. A split plot design with three replications was used in which irrigation treatments and cultivars were considered as the main and sub plots respectively. Plant height, number of pods per plant, 1000-seed weight, number of sub branches, plant dry weight, date of maturity, weight of pod coat per plant and grain yield were measured. Under both well-watered and water-stress conditions, irrigation treatments had significant (p < 0.01) effects on all the studied traits. Highly significant (P < 0.01) differences were observed among cultivars. The effects of interaction between two factors were highly significant for all traits, except number of sub branches and date of maturity. The highest (2331.6 kg/ha) and the lowest (1223 kg/ha) grain yield under normal conditions were obtained for A3935 and Clark cultivars, respectively. The highest (1524 kg/ha) and the lowest (815 kg/ha) grain yield under water stress condition were obtained for Maccal and Hercor cultivars, respectively. According to Duncan’s multiple range test for grain yield using pooled data, all the cultivars divided in tow classes. Maccal and A3935 with high grain yield in the first class and the other cultivars in the second class.

P 3.57 - A terrain-based crop modelling system to assess management and mitigation options of arable agriculture

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Much of arable agriculture is done on sloped land, especially in the Mediterranean, and terrain may exacerbate the environmental impact on crops causing extra yield loss from drought, heat, and frost. Such impacts on crop establishment, development and growth must be reconsidered because climate change is likely to aggravate them. Within a European project (EU-QLK-5-CT-2002-01313) we developed a modelling system that integrates (a) dynamic process models for agro-meteorology, soil hydrology and plant growth specifically targeting physical stress and drought-related yield loss, (b) spatial input data determining the effects of terrain and soil on water and energy balance, and (c) representative local or regional weather inputs or regional climate change scenarios (e.g. HadRM3). For crop management options we consider the selection of crops and varieties, variation of sowing date and density. Varieties can be characterised by a number of geno-/phenotypic parameters. We defined specific risk indicators of environmental and practical relevance (sowing and harvest window; crop cover and viability, yield and economic margins). For support of scientific and technological development we calculate water use efficiency, drought and heat stress units. In multiple simulations we generate probabilistic risk indicators for each climate, environment and management scenario to optimise agronomic adaptation and mitigation. These are being discussed with different user groups in regions with hill site arable, farmers and advisors, agro-business (breeders, technology), academics, and policy makers. We will demonstrate sample responses for current and future scenarios (terrain-climate-management) and discuss the procedure to rank management options, including variety selection.
P 3.58 - Evaluation of wheat landraces as a genetic source using for wheat improvement in cold dryland areas of Iran

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The importance of genetic variation for crop improvement programs is well recognized. Natural variations in the form of landraces are the major genetic resource for plant breeders. The gene bank institute of Iran conserves over 15,000 wheat genotypes, which are mostly landraces. Since 1997, in order to evaluate these genotypes for using in rainfed wheat improvement programs, 500 landraces each year were studied in observation nurseries. Cold and drought stress are main limitation factors for crop production in cold dryland areas of Iran. Previously, researchers in DARI declared that the most important selection factors are earliness in heading and maturity, high plant and peduncle height and high thousand kernel weight. For additional testing, after getting uniformed, selected vigorous landraces evaluated in preliminary yield trial and next in advanced replicated yield trials. After 7 years working, two landraces numbers 4-78 and 914-78 found which could produce 3-16% more grain yield comparing to Sardari as national check in several on-farm yield trials. Additional 30 landraces were selected from previous tests and 3 promising landraces are testing in uniform regional yield trials. Studying on morpho-physiological characteristics of selected genotypes showed that high genetic variations for some characteristics, despite of available varieties landraces, some of awn less and red spike lines were found to have more yield potential in comm. dryland conditions.

P 3.59 - Integrated research and development approach to sustainable yield improvement in semi-desert drylands: the case of Northwest Coast, Egypt

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Agricultural productivity has drastically declined in Egypt’s Northwest Coast region due to increased human and livestock pressures on a dryland semi-desert area of inherently poor and fragile resource base. The paper presents the experience of Matrouh Resource Management Project in employing community-based, participatory approaches to R&D, with ICARDA’s technical assistance, and participation of local Bedouin communities in one of the poorest and most deprived regions in the country. Agriculture is the main source of livelihood, but the cultivated land is only 6% of the total area. Rainfall, the main source of water for domestic and agricultural uses, is low and erratic, averaging 150 mm at the coast and declines rapidly inland. The barley-livestock system is dominant; and barley grown for livestock feeding is the principal crop, with small areas grown to melon and other crops. Fig and olive are planted in the wadis and on land pockets of relatively good soils along the coast. Crop yields are very low and highly fluctuated, opportunities for diversified cropping, off-farm employment and non-agricultural economic activities are rare. The paper highlights the methodology and achievements of the project in developing and introducing to Bedouin communities technological packages for sustainable improvement in crop yields and system’s productivity, under extreme water-limited agriculture. The paper focuses particularly on the impressive technology adoption by farmers and substantial impact on crop yields, agricultural production improvement and farmers' income. A special emphasis is given to the lessons learned from analyzing the factors of success and failure, particularly the important role the participatory, community-based approach has played for achieving the biophysical and economic impact, and the role of ICARDA in effectively linking research with development through R&D projects such as MRMP and the mutual advantages gained by all partners.
### P 3.60 - Comparative yield physiology between wheat and barley under Mediterranean conditions

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Although water is generally recognized as the most limiting factor for cereal production in Mediterranean regions, it has been found that poor N nutrition may be responsible for limited water availability. The main Mediterranean cereals are wheat and barley, being normally barley grown only in more stressful conditions. There have been few efforts in comparing wheat and barley performance in dryland Mediterranean conditions under a range of soil N availability to determine whether barley does actually perform better than wheat, and whether these eventually different performances are altered by N availability. In a field experiment initiating a series of trials investigating these issues, we grew wheat (cv. Soisson) and barley (cv. Sunrise) in Agramunt (a dryland site within the Mediterranean region of Catalonia, Spain) in 2003-2004. Wheat outyielded barley in the unfertilized treatments (4.58 and 3.60 Mg ha⁻¹, respectively) indicating that the higher yield potential of wheat was associated with better performance in a condition of relatively low yield. Wheat responded to N in these conditions far more markedly than barley, until it saturated its response at a rate of 120 kg N ha⁻¹, (yielding 7.46 Mg ha⁻¹), whereas barley responded linearly until the rate of 200 kg N ha⁻¹ (yielding 6.81 Mg ha⁻¹). Most effects of treatments on yield were due to the effects on the number of grains per unit land area ($r^2 = 0.91, 10$ df). In both crops increasing N availability clearly tended to increase WUE, a trait that was consistently though slightly higher in wheat than in barley.

### P 3.61 - Drought tolerance evaluation tests in durum wheat (Tritium durum Desf.)

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The aim of this work is to evaluate the degree of tolerance to water stress in five genotypes of wheat using five different tests (germination, chlorophyll fluorescence extinction, electrolyte leakage, water and osmotic potential) at 3 to 4 leaf stage while using a known sensitive and a tolerant variety as reference. All the tests used showed that the known tolerant variety is well adapted to water stress than the sensitive variety. The three other varieties showed intermediate values.
P 3.62 - Livelihood enhancement in rainfed rice farming through establishment of seed villages

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Sources and availability of seeds of rice varieties and productivity variations among the varieties procured from different sources were analysed using household survey data collected from 240 rainfed rice growers. Yield enhancing technologies have been spreading in dry land areas, but readiness of the farmers to adopt them when made available is questionable due to lack of timely availability of inputs particularly improved seeds. Share of public sector in seed distribution has been hovering around 20% in the Tamil Nadu state during the last one decade in case of rice. Due to non-availability of quality seeds at the right time and within a reasonable distance, farmers are using the seeds selected by themselves from their previous crops. Some times they borrow seeds selected from a good crop of the other farmers. However, seed is mostly recycling within the villages leading to poor yields. Rainfed yield of rice forms only 50% of irrigated yield mainly due to adoption of poor quality seeds. Farmers in rainfed areas continue to grow land races mainly due to inadequate availability of seeds of high yielding varieties. This in turn reduces the average productivity of the farms resulting poor income. Farmers were also of the opinion that higher germination was the major reason for using own seeds. Hence there is an urgent need to strengthen the seed multiplication and distribution of quality seeds and made them available in the production point by establishing seed village centers in the rainfed rice growing areas.

P 3.63 - Impact of drought on cropping pattern change and poverty in rainfed rice agriculture in Tamil Nadu, India

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The paper is based on the secondary and farm household survey data (240 farm households) cutting across the various water limiting rice production environments. There were seven drought years in Tamil Nadu during the last three decades. Agricultural growth has trickle down effect and such effect weakened during the drought period. Income inequality ratios (Gini ratio – rice) reveal that drought affected rice production in the state irrespective of the size groups and regions. Much of crop diversification was observed during 1990s as compared to 1980s as evident from the rate of growth of Herfindhal index, which was higher (2.23%) during 1990s as compared to 1980s (-3.95). During the last thirty years rice area declined by 3.5 lakh hectares due to drought and the reduction was almost 17%. Results further show that good rainfall is expected to discourage acreage diversification. Irrigation intensity has a positive and significant effect on acreage diversification suggesting that availability of irrigation water all round the year is expected to promote acreage diversification emphasizing the need for water harvesting. Coefficients of wholesale price index and productivity index reveal that farmers prefer to cultivate the same crops if they fetch higher income either through increase in productivity or product price. Expansion of area under rice was also noticed in the selected rice production environments due to increase in yield revealing that infusing high productivity traits in the drought tolerant rice varieties will enable the farmers to allocate some amount of land to other crops and such diversification can generate adequate income to alleviate the poverty in the fragile areas.
**P 3.64 - Effect of soil conditioners on peanut (Arachis hypogea) establishment and runoff control in early drought conditions**

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Product benefits related to Polyacrylamide (PAM) include enhancement of germination of plant seeds and erosion control. The study objective is to investigate polymer effects on peanut establishment and runoff control in an early occurring drought context. Two experiments were conducted using polymer at Ceraas station (Senegal). First, a greenhouse trial in 2003 was conducted, where polymer, peanut variety and water regimes were combined in a factorial design with four replications; a 17 mm irrigation water being used for sowing. Then, an on-station trial was conducted in 2004 using a rain simulator for the 30 mm intensive sowing rain event. For this experiment, polymer and runoff were combined in a factorial design with 3 replications. For both trials, measured data included soil water content and agronomic and physiological parameters. For the first trial, results indicated a significantly positive effect of polymer on the most drought-sensitive variety, namely Fleur 11, as compared with the 73-30 peanut variety. Polymer favored a shallow rooting pattern with roots being trapped on polymer due to improved water content conditions, unlike the absence of polymer which favored deep rooting pattern. Consequently, polymer also increased significantly peanut plant growth. For the second trial, despite the positive effect of the polymer on runoff control, observed correlative large aggregates had a negative effect on plant establishment. But upon peanut plant emergence, the polymer increased significantly plant water potential and plant biomass. These results suggest, that PAM application, owing to its long-term effect on soil water conservation can play a major role in the improvement of peanut establishment.

**P 3.65 - Evaluation of advanced wheat genotypes for freezing tolerance**

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Increasing tolerance to biotic and abiotic stresses is one of the major purposes in plants breeding in the world. Breeding for physiological traits against environmental stresses such as freezing is one of the most important programs for increasing grain yield. Twenty-two wheat genotypes that were different for growth habits, were planted in three replicated randomized block designs in Ardebil, Iran. Physiological traits measured were: leaf relative water content (LRWC), cell membrane stability (CMS), membrane damage percentage (%MD) and chlorophyll content (CHC). As well as some phenological traits e.g. emergence percentage (%E), days to heading (DTH), flowering (DTF), anthesis (DTA), maturity (DTM), grain filling period (GFP) and growth habit (GH). ANOVA showed that differences between experimental genotypes were not significant for LRWC, CRWC, CMS, %MD, %E, GFP. However, they had significant differences for CHC, flag leaf color (FLC), DTH, DTF, DTA and DTM. Analysis of polynomial regression did not show linear, quadratic, and cubic relations between grain yield and LRWC, CRWC, CMS, CHC, GFP, %E, DTH, DTM, DTF. While relations between yield with %MD was cubic, that with plant height and grain color was quadratic. C-73-5 genotype was the most tolerant wheat to freezing conditions in this investigation. After that Au/yt55/.../Grk79 and Bezostaya was tolerant.
P 3.66 - Sustaining dry land agriculture - An extension management approach

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Dry land farming in Indian agriculture occupies 67% of the cultivated areas, contributing 44% of the population and two-thirds of the livestock lives in these regions. Currently, irrigated areas produce an average of two tonnes of food grains per hectare while the average productivity in rain fed areas is only 0.7 to 0.8 tonnes per hectare. The fact that 90% of coarse grain cereals, 90% of pulses, 81% of oilseeds and 69% of cotton are grown under rain fed conditions. Extension management is one of the important prerequisites for sustainable agriculture. Therefore, it is essential that the extension personnel are made aware of the local resources for developing the managerial ability of their own to make them shift from traditional to cope with new demands, new problems and new challenges. Keeping in view the ever-increasing population, development of dry land agriculture, the depletion of natural resources, environmental pollution and limitations of sustainable agriculture, the present study was carried out. A total number of 200 farmers and 50 extension personnel were interviewed and appropriate statistical tools were applied to draw useful inferences. The results of the study found that the mean knowledge score of extension personnel was 68.42 out of a maximum possible score of 97, which is equal to 70.5%. It concluded that the extension personnel had a moderate level of knowledge about technological aspects of sustainability. The data further shows that 32.0% of extension personnel had a high level of knowledge about overall technological aspects of sustainability, followed by equal 34.0% of extension personnel were found to have a medium as well as a low level of knowledge regarding overall technological aspects of sustainability. The study further revealed that among individual method farm clinics, the extension personnel considered adaptive minikit trials most essential. Among the group methods, the extension personnel considered method demonstration, result demonstration and field day as most essential. The other methods of communicating farm technology were: participative approach, integrated service approach, introduction and use of computers in all government offices, social engineering, organization of rural youth clubs, linking users with data banks and expert personnel, non-formal education of rural youth, demonstration on slow moving technology, etc.

P 3.67 - Patterns of carbon isotope discrimination in olives (Olea europaea L.) in southwest of Morocco

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To locate drought-tolerant cultivars of olive (Olea europaea L.) the carbon isotope discrimination (Δ13C) was used in combination with geographical information system (GIS). Δ was measured in 15 olive growing sites located in the southwest of Morocco. The analysis revealed a geographic pattern of variation among the sampled sites (45 trees) with significant differences among the sites and among the trees within the sites. There is also a strong link with elevation with a positive correlation between Δ and the elevation. Intriguingly the sites that are distinct in terms of their Δ values are also distinct based on both image analysis and molecular analysis carried from our recent work. Preliminary screening based on Δ was conducted for further phenotyping purposes to develop rapid and cost-effective drought descriptors and techniques that will assist in the genotyping envisaged work of ten segregating populations of olive crosses developed at INRA Marrakech.
P 3.68 - Participatory plant breeding (PPB) as a tool for developing rice varieties for rainfed uplands

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Drought is most important abiotic stress which inhibits the plant growth and ultimately decreases the yield. A collaborative Research Project for rice improvement was started between BAU, Gramin Vikas Trust (An NGO) and Centre for Arid Zone Studies, University of Wales, Bangor, Gwynedd, U.K. with funding from DFID a bilateral project managed by GVT and Plant Sciences Research Programme of DFID in 1997 for developing the farmers preferred drought tolerant variety of rice through participatory plant breeding (PPB). This collaborative project was further strengthened by Rockefeller Foundation during 2003 initially for two years and now it has been further extended for four years from 2005 to 2009. Collaborative and consultative participatory plant breeding was carried out and finally Ashoka-200F (Birsa Vikas Dhan – 109) and Ashoka-228 (Birsa Vikas Dhan – 110) was developed and released. Both the varieties were developed after the consultation of farmers and also tested in the farmer’s field therefore both the varieties have many desired traits preferred by the farmers. Large number of crosses has been made by involving Vandana x IR-72, Vandana x IR-72975, Warda 45 x Ashoka-157, Sathi 85-3 x Ashoka162, PBRC-78 x Komal-13 and CH-45 x MT1 and all has been fixed. The bulks derived from the marker assisted selection programme for drought tolerance from Kalinga-III x Azucena has also reached to the stage of fix. Four to five lines have been selected by scientist and farmers for drought tolerant and higher yield. Some of these lines will be sent in AICRIP and state trials along with on farm testing. The seed production programme and dissemination will also be undertaken of the farmers preferred varieties through GO-NGO collaboration so that quality seed may be given to the farmers timely.

P 3.69 - Genetic analysis for yield and yield component traits in winter x spring wheat crosses

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Genetic analysis of yield and its component traits was studied in springs x winter crosses of wheat, using full diallel analysis. The experiment was conducted in two random environment. Significant genetic differences were exhibited by the materials used (five winter and five summer ecotypes) and their F1 crosses for most of the traits. Graphical and component analysis of genetic variances revealed significant additive give action for plant height, productive tillers plant-1, days to maturity and grain yield, whereas, components of variance due to dominance deviation were also significant for all the traits indicating greater magnitude of non-additive gene action in the inheritance of these traits. This greater magnitude of non-additive gene action is expected from the higher heterozygous nature of genotypes at most of the loci in the crosses resulting from the divergent nature of the gene complexes in spring and winter wheat ecotypes. Average degree of dominance estimated from component analysis was in the overdominance range for all the characters, but graphical analysis revealed that the dominance was in partial to complete dominance range. The upward bias in dominance variation in the component analysis might have arisen due to epistasis and/or linkage effects. For grain yield and grains spike -1 the dominance was unidirectional.
**P 3.70 - Evaluation of drought tolerance in wheat varieties (Triticum aestivum L.)**

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Drought tolerance of nine wheat varieties were studied in two different experiments. In the first experiment, effect of drought on post seedling stage were studied in green house in which seeds were planted in pots and irrigated up to emergence. Pots were not irrigated afterwards. Permanent wilting signs appeared 55-62 days after irrigation. At this soil metric potential (estimated by soil moisture release curve) was -9 to -10.7 bar. Biston and Sardary wilted later than other varieties (62 days and at -10.7 bar). In the second experiment drought tolerance of varieties were evaluated under field conditions. Wheat varieties were planted in Tabriz and Aligodarz dry land research in the fall of 2001. During growth period, soil temperature, growth stages and soil moisture content were recorded. Grain yield of Tabriz was more than that of Aligodarz. Biston and Sardari produced more grain yield in Tabriz and Aligodarz, respectively. Correlation coefficients among the yield some of the yield components, for example grain weight, in the two regions were high and statistically significant. Biston and Sardary which showed drought tolerance in experiment first also produced more grain in the field compared to other varieties.

**P 3.71 - Effects of drought stress on water use efficiency (WUE) in rapeseed cultivars under semi-arid climate of Mashhad, Iran**

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Water use efficiency was measured in rapeseed cultivars under drought stress in the farm. Stress levels were 80, 65 and 50% of water requirement. Shelters were used to preventing from precipitation effects. Cultivars were selected from a ranked list of cultivars formerly tested under water deficit experiments. Four cultivars were selected ranging from tolerant to susceptible including: Regent-Cobra, Okapi, SLM046 and Licord. Results showed that water use efficiency, based on biomass, in stressed plots was higher than control. The highest water use efficiency was obtained in 65% irrigation treatment with about 0.73 kg m\(^{-3}\) of water applied. Drought stress did not affect dry matter until bud stage. After that, there was a significant effect on cultivars yield. Results showed a distinct difference in canopy temperature between treatments, so that temperature of stressed canopies were closer to environment temperature. Leaf relative water content (RWC) was decreased by advancing the phonological stages.
**P 3.72 - Evaluation of synthetic hexaploid bread wheats (T. aestivum x T. turgidum x T. tauschii) under limited irrigation**

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Iran is located in the arid and semi-arid area with annual precipitation of about 250 mm per year. To evaluate the effect of water limitation during grain filling stage as the main concern during wheat growing season, one experiment was conducted at experimental research station Karaj, Iran. With 18 synthetic hexaploid (SH) wheat and 2 advanced bread wheat including drought tolerant and susceptible wheat cultivar (Kavir and Mahdavi respectively) as checks. Grain yield, yield components, and other agronomic traits were determined. Results showed that six SH (including CHEN//Ae. squarrosa (Taus.)//BCN CMBM 89, CROC-1//Ae.squarrosa (205)//kauz CLG90) and four sister lines of them had better performance and grain yield than the best check (Kavir). Within yield component thousand kernel weight was the most important factor affected by drought stress, which was much higher in the SHs and their derivatives compared to the best check was.

**P 3.73 - Dynamics of agricultural scenarios in relation to irrigation policy: the case of Romagna**

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Understanding how irrigation water is used by farmers in an irrigated area both in space and time is extremely useful for irrigation policies. In fact, the effects of irrigation policy making reflects on variations of irrigation practice and crop technology selection. From decisions taken at the farm level, changes of land fabric occur which can only be observed by means of appropriate tools. GIS technology, created to get a photographic (static) layout of the territory, is especially useful for policy making decisions, is asked to show information of the time dimension of the problems. The present investigation is based on a cluster analysis of survey data, and on a multi-criteria approach generating irrigation-related outputs of a set of scenarios, from which emerged the possibility to analyse expected adaptive behaviour of farm irrigation strategies. Maps of an area of Romagna are presented and discussed.
P 3.74 - Adapting the BIOTIC protocol to manage water deficits

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The use of subsurface drip irrigation continues to increase as ground water from the Ogallala aquifer declines in the Southern Great Plains region of the USA. Yield response of cotton to limited irrigation using crop canopy temperature as the water stress signal was evaluated in a 3-year field study. The study’s objective was to control subsurface drip irrigation in the deficit water application range, evaluate the stability of irrigation control across years, and measure crop performance. Multiple time thresholds, representing different levels of stress time, were used in the BIOTIC protocol for scheduling irrigation applications. Irrigation decisions were made daily and a constant irrigation amount was applied in response to irrigation signals in all time thresholds. Rain was automatically incorporated into the water input to maximize irrigation efficiency. The entire spectrum of annual rain amounts during the past 93 years was represented by the rains received in 2002, 2003 and 2004 (ranking 50th, 5th and 92nd, respectively). Particular emphasis was given to documenting the stability of irrigation and total water input among years by each time threshold. The performance of the automated irrigation system will be discussed emphasizing the stability of irrigation control, crop stress times, yield versus water input, and the contribution of rain to total water input for the different deficit water levels. The time thresholds responded to environmental differences among years by applying different amounts of irrigation; however, the relationship of the deficit irrigation amounts produced was consistent. This automated system provided accurate control of irrigation input without the requirement of daily irrigation decisions by the crop manager.

P 3.75 - Impact of furrow irrigation design and management on yield under water-limited conditions

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Furrow irrigation design and management parameters have a significant impact on crop yield. An appropriate choice and control of these parameters is required to increase crop production especially under water-limited conditions. For a realistic simulation of the highly dynamic water flow in the irrigation system, a physically based seasonal furrow irrigation model was developed. It consists of a 1D surface flow model, the 2D water transport model HYDRUS-2 and a crop growth model. The model simulates evaporation, transpiration, infiltration, soil moisture distribution, percolation, rooting depth, and leaf-area index at user defined locations along the furrow and final crop yield. A sensitivity analysis of the model input parameters was conducted to analyze the impact of the furrow geometry parameters, the irrigation schedule, and the irrigation application parameters on the yield of a corn crop under deficit irrigation. The analysis revealed that an optimally controlled irrigation schedule in combination with optimal water application parameters is more sensitive to the final crop yield as the furrow geometry. The new irrigation model shows a high potential to increase productivity of crops under water-limited conditions by improving furrow irrigation design and management.
P 3.76 - Drought stress effects on yield and yield components of soybean genotypes

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This research was carried out in summer of 2005 in Karaj, Iran. 49 genotypes of soybean evaluated in balanced lattice square 7x7 in two conditions of stress and non-stress with two replications. First all the data were checked and normalized by statistical procedures. We measured seed yield, yield components, biomass, root weight, phonological characteristics in normal and stress conditions. Irrigation in normal and stress conditions were done when 60 and 150 mm evaporation occurred from basin pan respectively. Results of Analysis of variance in stress and non-stress conditions showed no significant differences for seed yield, number of seed per pod in normal condition. Variations of coefficient were well in most characters. Analysis of means in normal conditions showed genotypes with number of 19, 32, 16, 18, 28, 37, were best and number of 7, 1 were most sensitive genotypes for most of characters. In stress conditions, genotypes with no of 19, 41, 36, 49, 14 were better and genotypes 1, 12, 25, 31, 2 were sensitive for most of the characters. In normal conditions weight of 100 seed for genotype number 2 was best and for genotype 23 (beljeska kasna) was least. Study of characters variations showed biomass, seed yield per plant, seed yield in plot and weight of root had maximum variations in genotypes under stress conditions. Therefore, we concluded based on measured characters genotypes 19 (L.D.8149), 32 (Chameston), 4 (M50 Williams 25 kr), 16 (Maccon), 18 (L.D.10) were best genotypes and genotypes 7 (Korona), 1 (Enterprise), 40 (hadgson) were most drought sensitive.

P 3.77 - Evaluation of soybean genotypes in drought conditions

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In this research, that is worked in summer in year 2005 in Karaj, Iran, 49 genotypes of soybean evaluated in balanced lattice square 7x7 in two replications and in two conditions of stress and non-stress. We measured seed yield and yield components and then all the data were checked and normalized by statistical procedures. After then adjusted datas by analysis of variance were obtained, we calculated ten drought indices as yp, ys, tol, mp, gmp, harm, ssi, dsi, sti, dri and then these indices calculated by principle component because of identification of resistance genotypes and then for obtaining dendogram indices and genotypes, we did cluster analysis. Results showed two first components can explain away 98.2% of total of variance. When we plotted two first components, results identified resistance genotypes from sensitive genotypes. Genotypes 19, 16, 18, 20 were the best genotypes and genotypes 48, 23, 47, 9, 4 were the most sensitive genotypes. We calculated cluster analysis for aforementioned indices and genotypes as well. Final results showed that L.D.8149, ks4694, Maccon, L.D.10, were best genotypes and korona, capital (urb), baj-maj, ks3494, M11 were most sensitive genotype in compare with others. Results of cluster analysis showed 3 classes as: first group were yp, ys, mp, gmp, harm; next group was tol and the last group were dsi, sti, ssi, dri. Genotypes clustered in to 5 classes by indices.
P 3.78 - Evaluation of yield and some characteristics of ten spring barley (Hordeum vulgare) varieties under limited and non-limited irrigation

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In order to evaluate yield and some morphological characteristics of ten spring barley varieties under non-limited and limited irrigation (irrigation until flowering) an experiment as two design based on Randomized Complete Block (RCB) with three replications were carried out. All varieties had no difference in the number of kernel per spike and flag leaf area two irrigation regimens. The irrigation treatments affected all measured traits except awn length, spike length and no of kernel per spike of main stem. The genotypes and irrigation treatment interaction had significant effects on grain yield and growing period. In non limited irrigation treatment Atlas 46/kavir and Gorgan/CM67/Pro/Suo varieties, had higher grain yield than other varieties, whereas, Suifu/Walfaire, Rihane/Alger-union, Atlas 46/kavir and Gorgan/CM 67/pro/suo produced highest yield. There varieties had greater STI (Stress Tolerance Index) compared to other varieties and showed more resistance to drought stress at flowering-grain filling period.

P 3.79 - Evaluation of triticale lines as a new crop for cold dryland areas in Iran

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Triticale is a crop with high production potential, high lysine content, cold tolerance and extensive adaptability in non-productive soils. So it can be considered as a new crop or a direct substitute for barley in animal feed rations in cold dryland areas. Low growth duration in spring sowing and low winter survival in winter sowing are the major problems of barley production in highlands. Breeders in dryland research institute in Maragheh, Iran started studying to find a potential triticale line. In 2001, several selected lines from SPII, Karaj nurseries evaluated in dryland condition. Observations showed that triticale comparing to wheat (Azar-2) could be one week earlier in heading but mostly late in maturity with less productivity. Since 2002, 320 hexaploid triticale lines that received from CIMMYT evaluated and studied in several observational and advanced yield trial nurseries. The results showed extensive variation on morpho-physiological characteristics and the best lines were selected for additional studies. Finally, until now two promising line were found. The line of 576-82 was somehow same as wheat (Azar-2) in maturity but earlier in heading with 8% more grain yield. 77-ITSN82 was 6 and 3 days earlier, respectively, in heading and maturity with 10% more grain yield.
P 3.80 - Developing high water use efficiency agriculture in China

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As development of biology water saving, getting more food for every drop is the aim in water saving agriculture; water use efficiency is the key research direction in the future of agriculture. In the different areas with different precipitation and water resources, there are different key research problems on drought resistance, water saving and water use efficiency. From passive drought tolerance, research turned to initiative drought resistance research, then turned to water saving research, and will turn to water use efficiency research in the future. There is an increasing tendency of water use efficiency in wheat evolution of high yield breeding programs, so that is must develop high water use efficiency breeding changed from drought tolerance and drought resistance breeding, because high water use efficiency breeding could combine drought resistance and high yield traits into one new variety. It is should be stressed that more every kinds of fertilizers should be put into low and middle yield fields for getting high yield and water use efficiency. In this paper, we suggest the new concept of high water use efficiency agriculture, that is a new type of agriculture system combining with high and new science and technology with market economy, and aims to achieve high water use efficiency, high economical benefit, high ecological benefits and society benefits at means by using untie water. That is the way forward for Chinese agriculture developing. Combined with the problem of the decreased grain yield in China in the last years and the water saving agriculture developing in the future, we analyze the reasons that grain yield decreased was because more force was put into industry and commerce, and less attention was paid to agriculture in the south of China and some economically-developed cities. So we suggest that for solving the problem of decreased grain yield, and transfer grain from the north to south of China, we should not only stress to develop water saving agriculture in the north of China, but also stress to develop high water use efficiency agriculture in the south of China. We discusses that the imperativeness and feasibility as well as the necessity of developing high water use efficiency agriculture in China for these aspects: security of grain and economy and water resources, agricultural resources in the north and south of China, regulating agricultural structures, agronomic methods for drought resistance and water saving, high yield crop breeding and high efficiency water resource management.
This research has been performed for the recognition and resistant of genotypes to salty, spring wheat and finally presentation of resistant genotypes in the generation stage in the area of 450,000 hectare. This area is located in the plain of Aji chai in the west of Tabriz which stretched to the banks of Oramih Lake. The salty river of Aji ehai has enough water in the early spring and in the middle of fall and it provides the water for cultivation of this plain along with well and rainfall water. But in the late spring and in summer the quality of the water becomes unsatisfactory because of decline in the rainfall. One of the ways to encounter with these dangers is recognition and representing the genotypes that are resistant to these conditions of the area. So this must be started in the implantation stage by evaluating and recognizing the reaction of plants. The experiments totally have been performed in the laboratory of shabestar Islamic Azad university of agriculture faculty in two stages. In the first stage the seeds of 24 lines of 20nt native masses with two masses of yazlig 1, 2 exposed to densities of 0, 25, 50 and 75 ml of pure NaCl. The experiments were performed on factorial form with completely randomized design with four repetitions. The statistical analysis of project was done after counting and recording the figures and 18 genotypes out of 26 genotypes were chosen for the study in the second stage. In the second stage solutions of the water of the Aji chai with the electrical conduct of 3000, 6000, 9000 and 12000 mic/cm provided and this along with pure water to the selected seeds with four repetition. Statistical analysis of both stages shows that there are meaning significant differences between genotypes, different densities and also cross effect of genotypes that were resistant in the first stage showed resistant in the second stage. Most lines resulted from Basmenj native masses including two masses of yazlig 1, 2 and two lines of paresh 1, 2 had more percentages of generation in both stages and also the meaningful generation decline in increase of amount of density in sensitive genotypes have been observed. We hope the results of this research have become basis for the next researches in recognition and discovering resistant genotypes for cultivation in the area or genetic sources for correction of compatible of more harvesting cultivate figures for Aji Chai.
P 4.01 - Root aquaporin expression in mycorrhizal plants drying under water deficit conditions

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Although the discovery of aquaporins in plants has resulted in a paradigm shift in the understanding of plant water relations, the relationship between aquaporins and plant responses to drought still remains elusive. Moreover, the contribution of aquaporin genes to the enhanced tolerance to drought in arbuscular mycorrhizal (AM) plants has never been investigated. Hence, we studied at molecular level whether the expression of aquaporin-encoding genes in roots is altered by the AM symbiosis as a mechanism to enhance host plant tolerance to water deficit. In this study, genes encoding plasma membrane aquaporins (PIPs) from soybean and lettuce were cloned and its expression pattern studied in AM and non AM plants cultivated under well-watered or drought stress conditions. Results show that AM plants respond to drought stress down-regulating the expression of the PIP genes studied and anticipating its down-regulation as compared to non AM plants. The possible physiological implications of this down-regulation of PIP genes as a mechanism to decrease membrane water permeability and to allow cellular water conservation is further discussed.

P 4.02 - Adaptation to drought in Beta species

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Water deficit is responsible for significant yield and quality losses in sugarbeet (Beta vulgaris ssp. vulgaris). Genetic variation for the response to drought is necessary. Though sugar beet can be considered a fairly tolerant species, due to its relatedness with the sea beet, Beta vulgaris ssp. maritima, it has often been reported that sugar beet commercial varieties show limited variability for the productive response to limited water supply. Four Beta accessions (one sugar beet, one leaf beet, one garden beet and one wild sea beet accession) were grown in a controlled environment. Sixty days after emergence, the water supply for half of the plants was suspended. One cm. leaf discs were excised from the plants, to measure the Relative Water Content and the osmotic potential O P_i. The values ranged, in control plants, 90-95% for RWC and -0.85 Mpa for O P_i, with no differences between genotypes. At day 10 from water withdrawal, RWC and O P_i started declining in all genotypes. RWC and O P_i values were used to calculate the O P_0, i.e. the osmotic potential due to the concentration effects caused by tissue water loss. The difference between the two regression lines of RWC vs. O P_i and RWC vs. O P_0 at RWC = 60% is a measure of osmotic adjustment (OA), the active mechanism of solute accumulation existing at different extents in plants. The OA values ranged from 0.70 for leaf beet to 0.95 for sea beet, in agreement with the adaptation of this wild subspecies to low osmotic potential environments.
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Triticale (x Triticosecale Wittmack) is a human-made crop which has become increasingly important in Australia and other countries. A number of experiments set out to examine plant water relations parameters with particular reference to osmotic adjustment (OA), the variation between triticale genotypes, and the effect of OA on the yield of this crop in response to water deficit. Furthermore, the effect of factors such as the rate of development of water deficit and plant growth stage on OA was assessed. Since other physiological plant traits are also important in plant drought tolerance, and to find any possible correlation between OA and other plant traits, a number of other plant traits were also assessed. Variation was found between triticale genotypes based on plant water relations and OA in response to water deficit in the first experiment. The levels of OA found in the first experiment for different triticale genotypes changed from 0.0 MPa to 0.74 MPa. However in next experiments the four triticale cultivars selected from the first experiment showed even higher degrees of OA, varying from 0.34 MPa to 2.23 MPa. A further experiment showed that the relatively low degree of OA in the first experiment was likely due to the fast rate of water deficit development. Therefore it is suggested that special consideration should be given to this matter in studies about OA in different plants and crops. There was no strong correlation between OA and grain yield, however, the experiment on water deficit rate showed that, when the rate of development of water deficit is slow, OA will show a stronger correlation with grain yield. Overall, the degrees of OA in response to water deficit found for the triticale genotypes were higher than those reported for other cereals. Although it may be expected that triticale performance is the same as wheat, the results of this work showed that it is not necessarily the case. Moreover, triticale is a diverse species and cultivars arising from different breeding and selection environments are expected to have widely different responses to water stress.
**P 4.04 - Osmolyte production, subcellular compartmentation and function in protein folding in the halotolerant Limonium latifolium**

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Limonium latifolium, a salt tolerant member of the Plumbaginaceae family, is known to accumulate osmolytes from different metabolic origins. All these substances have been assumed to be involved in metabolic and osmotic homeostasis. This unusual metabolic diversity is not explained and gives rise to the hypothesis that specific roles may be attributed to each of these presumed compatible solutes. Their accumulation processes, except that of proline (Pro), were not found to rely specifically on salinization and it is suggested that salt tolerance of *L. latifolium* might partly result from the ability to generate an osmoprotective cellular environment through a constitutive production and deposition of organic compounds. Moreover the internal compartmentation of Pro and β-alanine betaine (AB), the predominant osmolytes, was investigated in order to determine their actual contribution to osmotic adjustment at the subcellular level. Surprisingly it was found that the main Pro and AB pools were localized in the vacuole. Nevertheless significant concentration of Pro could be detected at the cytoplasm level under salt treatment. AB whose amount was not affected by salt was shown to be partly delocalized from the vacuole to the cytoplasm and that could be assumed to have a physiological significance for haloprotection. We have further investigated the thermoprotective and haloprotective properties of osmolytes occurring in Limonium in comparison with structural homologs found to be accumulated in other plant systems. Thus we took the opportunity to assess in vitro their properties in restoring or maintaining protein folding or as antioxidants and clear and distinctive effects were pointed out at that levels.

**P 4.05 - RAB16-type dehydrins in Lupinus albus: pattern of protein accumulation and gene expression in response to drought stress**

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Dehydrins are a subgroup of LEA proteins (late embryogenesis abundant) that accumulate in various plant tissues in response to environmental stresses (e.g. cold and drought) and during seed maturation. Although their functions are not well understood, they have been assumed to assist cells in tolerating dehydration, namely by stabilizing other proteins or cellular membranes. Lupin plants (*Lupinus albus*) are able to withstand periods of severe water shortage and previous work suggested that the stem plays a central role as a survival structure. To investigate dehydrin (DHN) involvement in this strategy we studied tissue specific protein accumulation of RAB16-type DHN in lupin during an imposed progressive water stress. Regarding the pattern of protein accumulation, differences were found between the different tissues tested (leaves, stems and roots). In leaves and roots, the accumulation of the RAB16-type DHN was independent of the water status whereas in the stem, DHNs only were detected under water deficit conditions. RT-PCR analysis showed a constitutive accumulation of RAB16-type DHN mRNA regardless of the tissue or the water status of the plant. Hence, unlike most DHN characterized so far, the lupin RAB16-type DHN in the stem is regulated in a post-transcriptional manner under drought stress. Furthermore, the results suggest that this group of proteins is likely to have tissue specific roles.
P 4.06 - Drought stress effects on yield, quantitative and qualitative characteristics of new sunflower hybrids

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In order to study the effects of drought stress on quantitative and qualitative characters of 13 new sunflower hybrids, two distinct experiments were conducted in karaj seed and plant improvement institute- oil seeds research department in 2002. Both experiments were done as a complete block design with three replications. Irrigation of control experiment was done based on 60 mm evaporation from evaporation basin class A. second experiment (drought stress ) irrigated when 180 mm water was evaporated from evaporation basin. Drought stress started before reproductive stage. Hybrids parents were Restorer lines as R28, R43, R82, R217, R219, R220, R244, R256 and 3 CMS lines as CMS 60/52, CMS19 and CMS 31. The results showed that water stress reduced seed yield due to decreasing of yield components such as head diameter, seed number, seed weight and Plant height. Effective seed filling period, harvest index, leaf area index and seed oil content were also decreased by drought. Among 13 hybrids CMS19 x R43 (Azargol) had the highest seed yield in combination of two conditions (stress and control). The results of drought stress indices showed M.p and G.M.P had significant correlation with yield in control and drought conditions. Based on M.P and GMP indices CMS31 x R28 (Goldis), CMS19 x R43(Azargol),CMS 60/52 x R256 and CMS19 x R217 were the best hybrids.

P 4.07 - Effect of drought-stress on expression profiles of fructan-producing potatoes

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Moderate drought-stress is an important environmental parameter for Solanum tuberosum cultivated on light soils in temperate climates. We compared transgenic potatoes that synthesise the compatible solutes fructan with their parent cultivar Désirée. Their long-term response to moderate drought-stress was studied under controlled conditions. Different water supply regimes were imposed by cultivating plants in vessels that were linked to the water supply by conducting bodies of different water transport resistances, thus leading to defined, constant water contents of the soil. Plants cultivated on the drought stress treatment showed a 50% growth reduction compared to the controls. Under these conditions, S. tuberosum did not alter the osmotic potential of leaf cell sap, but decreased the saturation weight/dry weight (SW/DW) ratio of the leaf. Fructan producing potatoes adjusted the SW/DW ratio less than the parent cultivar. RNA-expression profiles were generated for leaves from drought stressed and control plants using CGEB tomato cDNA slides. Candidates for drought stress induced genes were identified employing the filtering criteria spot quality, induction factor (> 1.7-fold) and probability in a two-way ANOVA F-Test (P < 0.1). Among the candidates were known drought-stress-induced genes like the dehydrin TAS14 and genes involved in ethylene and jasmonic acid synthesis. In addition, several drought stress induced genes were involved in cell wall synthesis. Together with the alteration in the saturation weight/dry weight ratio, this suggests that alteration of the cell wall may be part of the tolerance mechanism of potato to moderate drought stress.
P 4.08 - The xanthophyll cycle in response to drought stress in Arbutus unedo L.

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Mediterranean plants should tolerate difficult environmental condition because drought stress is frequently combined with elevated temperatures and high irradiation. Mediterranean plants have developed several mechanisms in order to protect themselves from these stresses. The xanthophyll cycle is a photo-protective pathway located in the thylacoid membranes that consist in the reversible enzymatic conversion of violaxanthin in zeaxanthin during light stress. Zeaxanthin is able to defend the photosynthetic apparatus from damage caused by photon overload dissipating light energy as heat. In our study, we analyze the water deprivation stress imposed on strawberry tree and its effects on the xanthophyll cycle. We focused on three main aspects: chlorophyll fluorescence, gene expression variation of the cycle enzymes and cellular content of ascorbate (a co-substrate of cycle reaction). The fluorescence data collected show a damage in the PSII reaction center during the highest stress period and a coincident drop in xanthophyll dependent thermal dissipation. This unexpected data couldn’t be explained by gene expression study because it suggest an induction of violaxanthin de-epoxidase (the enzyme that produce zeaxanthin) and we observe that ascorbate isn’t limiting for the biochemical reaction because its content remain high and stable. Our hypothesis is that the damage to PSII blocks the electron flow of the photosynthesis avoiding the formation of ΔpH across thylacoid membranes that is required for enzyme activity of violaxanthin de-epoxidase.

P 4.09 - Effect of drought stress followed by a rewatering period on physiological parameters and the proteome of Populus x canescens (clone 717-IB4)

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Drought is one of the most important environmental stress factors limiting wood production of forest trees. The physiological mechanisms involved in plant water-stress adaptation are associated to changes in genes expression. These genes are involved in osmotic adjustment, cellular protection, damages limitation etc..... and were mainly studied in model species and crop plants. Such investigation remains in its infancy in trees. The aim of our work was to study the effect of a water stress followed by a rehydration period in a woody plant model: Populus x canescens (Populus tremula x Populus alba (clone 717-IB4)). The identification of proteins involved in this process will enable us to understand how these long lived organisms respond to drought and eventually derived diagnostic markers for genetic resources management such as improving the drought tolerance of clones of interest. Populus x canescens cuttings were grown in controlled conditions. The stress intensity was estimated by measuring predawn leaf water potential, leaf relative water content, leaf growth, leaf conductance and maximum photosynthesis. Proteome analysis was performed using 2D-PAGE. Proteins were extracted from leaves and cambium tissues isolated from control plants (-0.4MPa), stressed plants (-1.6MPa) and rehydrated plants (-0.4MPa). Twenty five differentially expressed proteins were identified and for three of them tandem MS data allows their function to be determined. These proteins correspond to a glutathione s-transferase, an oxygen-evolving enhancer protein 2 chloroplast precursor, and a 3,4-dihydroxy-2-butanoic kinase.
**P 4.10 - Evaluating rice genotypes at the vegetative stage for drought recovery ability and associated traits for water-limited environments**

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Water stress is a serious production constraint in upland rice ecologies in many countries in Africa. In Mali rainfall is monomodal and often unevenly distributed, and thus Upland rice is subjected to varying degrees and duration of drought stress, especially at the vegetative stage of the crop development. Drought tolerant cultivars are thus needed to assist reduce yield loss and help stabilize production. To meet this objective sixteen genotypes comprising eight *Oryza glaberrima* Steud, six interspecific (derived from crosses between *O. sativa* and *O. glaberrima*) and two improved *O. sativa* L. ssp japonica, together with the drought tolerant check, OS6, were screened for drought tolerance in two experiments at the vegetative stage during the dry season of 2004 and 2005 at Samanko Research Station, Bamako in Mali. In both stressed experiments irrigation was applied for 35 days after sowing after which it was withdrawn for 21 and 43 days in 2004 and 2005, respectively. During the period, drought score, leaf rolling, leaf area index, specific leaf area, plant height, tiller number, relative leaf water content and Biomass (fresh and dry) were rated. Drought recovery ability was scored at 3 and 10 days after resuming of irrigation. Faster drought recovery was significantly associated with less drought score (little leaf drying), fewer tillers and larger leaf area index at 3 days and 10 days after resuming irrigation. Less relative leaf water content was found to be significantly associated with faster drought recovery at 3 days of resuming irrigation. Effects of genotype-by-environment (GxE) interaction were significant in the two stressed experiments, and WAB 450-I-B-P-103-HB is most outstanding genotype for the aforementioned traits but with fewer tillers. The best four genotypes are WAB 450-I-B-P-103-HB, WAB 880-1-38-13-1-P1-HB, NERICA 3 and CG 14 for faster drought recovery and were significantly better than OS 6 in the experiments.

**P 4.11 - Effects of drought stress on chlorophyll fluorescence parameters, chlorophyll content and grain yield of wheat cultivars**

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Chlorophyll fluorescence quick variation could be used as an index for evaluation of tolerance in plants to environmental stresses. So an experiment was conducted using 3 wheat varieties (Chamran, Marvdasht and Gaspard) with seven irrigation levels under filed conditions an a factorial in a randomized complete block design with four replications. Chlorophyll fluorescence parameters were measured on plant flag leaves about 3 weeks after flowering. Photo-system II photochemical capacity was calculated from the ratio of variable fluorescence to maximum chlorophyll fluorescence (FV/ FM). In addition, T1/2 and FV were evaluated. Relative water content and flag leaf chlorophyll was measured. Results showed that different irrigation levels effects on the FV, FV/ FM and T1/2 did significantly (P ≤ 0.05) and on the F0,FM did not significantly. Effect varieties, except for T1/2 did not significantly affect on the fluorescence's parameters, but Duncan’s Multiple Range Test showed significant differences within the treatments. Both, varieties and different irrigation levels affected chlorophyll content, RWC and grain yield (GY) significantly (P<0.01). Mean of FV/FM, FV, T1/2 and FM were declined as soil water content was decreased, but F0 was almost remained constant for all the treatments. High yielding varieties had high values of T1/2,FM,FV/ FM,FV, chlorophyll content and RWC. The highest correlation coefficient were found between grain yield with FV and FV/ FM(r = 0.6**), while the lowest correlation coefficient was detected between grain yield and F0 (r = - 0.04ns). Existing similar pattern of variation in fluorescence parameters in all varieties indicates that high yielding varieties can avoid the effects of drought stress during grain filling period, and the result is confirmed by correlation between fluorescence parameters and RWC.
P 4.12 - Proline accumulation promoted by different signalling pathways in Arabidopsis thaliana and in Thellungiella halophila

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Accumulation of proline is a widespread plant response to environmental stresses and proline is thought to play a role in the adaptive response. Despite the importance of proline accumulation in response to stress and in contrast to metabolic events involved in proline accumulation, the signalling cascades regulating proline metabolism are still poorly known. Our current efforts are focused on elucidating the signalling pathways involved in the regulation of proline metabolism, and understanding the role of proline accumulation in whole-plant response to osmotic-stress tolerance in the two model species, the glycophyte, Arabidopsis thaliana and the halophyte, Thellungiella halophila. To identify the signalling components involved downstream of hyperosmotic stress, we performed a pharmacological approach. Twelve-day-old Arabidopsis seedlings have been treated with inhibitors of key signalling elements. The effects of these inhibitors have been investigated on proline accumulation as well as on transcriptional and translational levels of key marker genes (P5CS, δ-OAT and ProDH). Phospholipase D are negative regulators of proline metabolism under normal conditions. When this regulator is abolished, plants show a higher proline responsiveness to osmotic stress (Thiery et al. 2004). On the other hand, Ca²⁺ acts as a positive regulator of proline biosynthesis. The origin of Ca²⁺ from either extracellular stores or through phospholipase C activity was also addressed. In conclusion, we provide experimental evidence that positive and negative regulators are involved in the fine regulation of proline metabolism upon hyperosmotic stresses. Our study has defined a critical role of lipid signalling pathway in proline accumulation in A. thaliana and also in T. halophila.


P 4.13 - Expression profiling of near isogenic lines for a major QTL influencing leaf ABA in maize

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Abscisic acid (ABA) plays an important role in the adaptation to drought. Sets of maize backcrossed isogenic lines (BDLs), which differ for one major QTL controlling leaf ABA concentration (L-ABA) have been developed (Landi et al. 2005, Mol. Breed. 15:291-303) starting from a cross between IABO78 (low L-ABA) and Os420 (high L-ABA). Previous work has shown a strong effect of this QTL on L-ABA and root architecture, with the allele provided by Os420 determining higher L-ABA concentration (+ allele). The objective of this study was to monitor expression changes in leaves of two pairs of BDLs (IABO78 (+/+)) and (-/-); Os420 (+/+ and (-/-) subjected to slow-drying conditions in soil. Plants subjected to well-watered (control) and drought stress (decrease in leaf RWC of ca. 5 and 10%) treatments were grown in greenhouse and leaf samples for RNA isolation were collected near anthesis. For this purpose, we used the rice whole genome GeneChip® in collaboration with Syngenta. Our results confirmed the QTL effect on L-ABA concentration in response to dehydration stress and the analysis of changes in gene expression allowed us to identify 121 stress-modulated probes (2-fold difference). Genes differentially expressed between congeneric strains sharing the same genetic background and differing only for the parental alleles at the target QTL represent candidate genes for the target QTL. The availability of the complete rice genome sequence allowed us to identify which of the differentially stress-modulated transcripts were localized in the rice chromosome segment syntenic to the maize chromosome region carrying the major ABA-QTL.
The activities of cysteine proteinases (EC 3.4.22) respond dramatically to water deficiency and in some cases they rise to 90% of the total proteolytic activity (Zagdaska and Winiewski 1996). They are involved in degradation and rebuilt of proteins in response to different external stimuli and they also play a house-keeping function to remove abnormal, misfolded proteins (Grudkowska and Zagdaska 2004). To understand the role of these enzymes in the response to water deficiency, wheat genotypes differing in dehydration tolerance were examined. Experiments were carried out on two cultivars of spring wheat (Triticum aestivum L.) differing in dehydration tolerance of flag and fifth leaves of sensitive (Alkora) and resistant (Eta) cultivars. The cysteine proteinases activities were low in fully turgid control leaves of genotypes differing in dehydration tolerance. However, their activities increased linearly with the increasing water deficit in wheat leaves and the enhancement being lower in tolerant genotype and the highest in sensitive genotype. Electrophoretic analysis (SDS-PAGE co-polimerized with 0.1% gelatin) revealed an appearance of three additional cysteine proteinase-active bands from water deficient leaves of both cultivars. The induction of the additional bands of cysteine proteinase activity suggests that specific vacuolar enzymes are potentially involved in the plant response to dehydration. The removal of cysteine proteinase activities in the presence of synthesis inhibitors (cycloheximide and cordycepin) suggests that cysteine proteinase are induced and synthesized upon water deficiency.


P 4.15 - Antioxidative responses to water stress among three Safflower (Carthamus tinctorius L.) cultivars

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Antioxidant enzyme activities which include catalase, superoxide dismutase and glutathione peroxidase were determined in three spring safflower (Carthamus tinctorius L.) cultivars Arak 2811, KH62-620, IL117 subjected to water stress by withholding water until the soil water content reached 12%. The activities of antioxidant enzymes were significantly high in the water stressed leaves. Higher antioxidant enzyme activities were observed in the leaf extracts of Arak 2811 while the lowest activities were recorded with cv. IL 117. Almost lower rate of electrolytic leakage were noticed in the leaves of Arak 2811 and KH62-620 under water deficit. Higher seed yield stability were observed in cv. Arak 2811 in the field. Our data demonstrated that among three safflower cultivars, cv. Arak 2811 has efficient antioxidant characteristics which produce better protection against oxidative stress in leaves under water limited condition. We concluded those varieties having more uniform germination in laboratory when exposed to an osmoticum may have more seed yield stability in the field and higher antioxidant enzymes activity as well. Plant height, seed 1000 weight, bull diameter, number of seeds per bull, number of bulls, relative water content (RWC) and membrane leakage were measured. Result, showed that there were significant differences (P < 0.01) between activity levels of superoxide dismutase, catalase and glutathione peroxides in the irrigated and drought stress treatments. The activity of all antioxidant enzymes were increased under drought stress in all varieties. Among varieties, Arak 2811 showed highest amount of antioxidative enzymes showing higher drought tolerant in compare with other varieties. Germination and seed yield susceptibility were calculated by two method (Fischer and Maurer 1987; Habibi et al 1995). Results showed the susceptibility percent of germination in Arak 2811 to drought stress (mannitol) treatment was low. In this variety SOD, CAT and GPX content were high. This variety also produced more bull yield and higher seed yield stability in the field. We concluded those varieties having more uniform germination in laboratory when exposed to an osmoticum may have more seed yield stability in the field and higher antioxidant enzymes, hence high tolerance to drought stress conditions.

P 4.16 - Genotypic differences in the response of maize leaf growth to chemical and hydraulic signals

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It is well known that drought reduces leaf growth by reducing water potential and turgor of elongating cells (hydraulic signals). However, many reports demonstrated that root-sourced signals (chemical signals) may also control leaf growth of plants in drying soil. The aim of presented paper was to compare reactions of two maize genotypes, differing in leaf elongation rate (high-LER and low-LER), to both types of signals. Plants were grown in a growth cabinet and exposed to: soil drought or in leaf elongation bioassay to different pH (5-7), different concentrations of ABA (10⁻⁶ M and 10⁻⁸ M) or pH vs ABA solutions. During drought experiments LER, leaf water potential, xylem pH and endogenous leaf ABA content were measured, although LER in leaf bioassay. Obtained results showed that drought and bioassay treatments (pH, ABA and pH vs ABA) differently influenced LER but the magnitude of the changes depended on investigated genotypes and their sensitivity to hydraulic and chemical signals. They are discussed in terms of a regulatory role of hydraulic or chemicals signals in determining differences in growth rate among investigated maize genotypes.
P 4.17 - Resurrection geophyte Ranunculus asiaticus: changes in cell structure and protein content during annual life cycles of desiccation and re-hydration

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Ranunculus asiaticus L. (Turban Buttercup), originated in southwestern Asia and the Mediterranean region, is a perennial geophyte with bright flowers varying in colour from white and yellow to pink and red. Underground storage organs of R. asiaticus are annual crowns with several renewal buds and tuberous roots. R. asiaticus represents a special type of resurrection geophyte, which survives unfavorable environmental conditions in the form of underground storage organs. This species is ecologically adapted to annual cycle of desiccation and resurrection, and can serve as a model for investigations of mechanisms of plant adaptations to long periods of heat and drought, as well as desiccation tolerance of underground organs, especially roots. The annual developmental cycle of tuberous roots was studied with respect to structure and content of their cells, to understand how these roots are adapted to desiccation, high temperature and rehydration. The roots of R. asiaticus undergo profound changes in their cellular structure and contents during their annual life cycle, incorporating phases of growth, cell wall and protein deposition, desiccation, and degradation of the wall and cellular contents. The accumulation of proteins presumably serves as a store for nitrogen to support early re-establishment of the shoots, and some proteins may have a protective function under high-temperature and/or desiccation conditions. In addition, binding of water by pectin in the cell walls could serve as a protection mechanism during desiccation and rehydration to limit stress-induced damage to the cells, as well as serving as a potential source of carbon for the growing plant when mobilized.

P 4.18 - Evaluation of response of O. glaberrima S to drought stress through analyzing leaf rolling and xylem exudation rate

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Drought has been recognized as the primary constraint to rainfed rice production. For improving the rice production on rainfed ecosystem, we need to develop the resistance of rice plants to drought. Rice plants have some strategies for drought stress. One of them is increasing root length and density, which results in keeping the absorption of water and high water potential of leaf. Rice cultivars which have higher water consumption in drought stress are advantage to the rice productivity, because rice plants can still keep CO₂ fixation without closing the stoma. O. glaberrima cultivars ranked highest in dry matter production under water stressed conditions, suggesting that O. glaberrima cultivars will have high water consumption ability under drought stress. However, the knowledge of physiology of O. glaberrima is shortage. In this study, we evaluated drought resistance of O. glaberrima from point of view of water consumption through analyzing the transpiration of leaf under drought stress.
P 4.19 - Morpho-biochemical characterization of wheat genotypes under drought stress

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Drought is one of the major abiotic stresses reducing grain production in wheat. The aim of the present study was to evaluate the morpho-biochemical characters which may be relevant to tolerance of bread wheat genotypes. As abiotic stress is associated with oxidative damage, augmentation of the antioxidative defences plays a pivotal role in preventing oxidative stress in plants. During present studies activities of Peroxidase (POD), Superoxide dismutase (SOD) concentration of Malondialdehyde (MDA) and total proteins was studied. Seeds of local wheat genotypes were grown under irrigated and three drought stress conditions. Morphological parameters studied included plant height, spike length, total number of grains, grain weight and number of spikelets. The tolerant wheat genotypes seems to have lesser reduction in plant height as compared to the sensitive ones. Besides, positive significant correlations have been found between mean plant height and mean spike length, grain weight, total number of grains and number of spikelets. Tolerant genotypes under stress showed higher levels of POD and SOD as compared to sensitive ones. Levels of MDA were more in sensitive cultivars, which is an indicator of membrane damage. It may be concluded that an optimum plant height claims to be positively correlated with productivity of the plant. Increased SOD and POD activity could be one of the reasons for tolerance against water deficit in drought tolerant genotypes. These variations in antioxidant enzymes can be used as biochemical parameters for selection of drought tolerant wheat genotypes.

P 4.20 - Determination of dehydration-induced physiological changes and molecular responses in rice plants

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This study aims to determine water loss and physiological and molecular alterations as exposed to dehydration stress in rice plant. Rice seedlings were grown in a nutrient solution within a managed environment chamber prior to the imposition of the dehydration stress. Dehydration was imposed through exposing the roots of plants in the air. Water loss of intact plant was determined by continuous weightings till 300 minutes after starting the imposition of dehydration. The imposition of dehydration caused significant loss of internal water, resulting in 44 % out of initial water content at 300 minutes long dehydration. Dehydration imposition also reduced the rate of water loss per minute per gram dry weight from 14.2 to 2.1 mg min⁻¹ g DW⁻¹. These results indicate that the dehydration imposition causes osmotic stress due to water loss in tissue. The dehydration stress also reduced significantly relative water content and osmotic potentials with time. The dehydration stress also induced the mRNA expression of drought-induced protein (Dip1), drought-induced hydrophobic protein (DRR2) and mitogen-activated protein kinase (MAPK). MAPKs were mostly expressed before 20 % water loss out of the initial water content. However, Dip1 and DRR2 were strongly expressed after 20 – 40 water loss out of the initial water content. Further works will be done to find a reliable methodology to distinguish drought-tolerant and – sensitive plants based on the findings.
P 4.21 - Adaptation to drought stress among spring wheat cultivars of different decades in semi-arid China. A differential responses of cultivars to drying soil under field conditions

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A field experiment was conducted in a rain shelter to investigate responses of eight spring wheat cultivars of decades to soil drying. The treatments included: (1) no water supply throughout developmental period (extreme stress, ES), (2) 30 mm water supply in seedling period (severe stress, SS), (3) seedling 30 mm + tillering 30 mm (intermediate stress, IS), (4) seedling 30 mm + tillering 30 mm + jointing 30 mm (mild stress, MS), (5) seedling 50 mm + tillering 50 mm + jointing 100 mm + booting 50 mm (well-watered group, CK). 

Monkhead and Jinby (old cultivars), and Plateau602 (recent cultivar), having > 300 g/m² Root biomass (RB) within 2 m-depth soil, had relatively “large root system”, compared with the other five non-old cultivars (<240 g/m²). Linear relationship existed between soil moisture and yield performance. In ES group, RB was significantly correlated with grain yields among cultivars. Meanwhile, both lethal leaf water potential (LLWP) and survival days (SD) were not correlated with MRSB and GY in ES group. Conversely, in IS and MS treatments, RB was not correlated with MRSB and GY. But in IS and ES treatments, both LLWP and SD were significantly correlated with GY. LLWP and SD were positively correlated with MRSB only in MS group. In the mild and intermediate stresses, “large root system” plays a recessive role, and LLWP and SD play a dominant role; whereas in severe and extreme stresses, their roles come to a converse.

P 4.22 - Dissecting the role of the H+PPase AVP1 in plant growth, nutrition, and response to abiotic stress root engineering, auxin transport

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Cells expend as much as 50% of their total intracellular energy reserves to maintain gradients of ions across their membranes. The electrochemical potential of these ion gradients represents stored energy. Plants and fungi are similar in that they use proton (H⁺) gradients as the “currency” with which to mediate transport of organic and inorganic ions, whereas animal cells use Na⁺ gradients as the driving force. The H⁺-PPase AVP1 is classically thought of as maintaining the acidic nature of the plant vacuolar compartment. Here we report that AVP1 also plays a critical role in facilitating auxin transport and thereby coordinating development. AVP1 overexpression resulted in enhanced cell divisions at the onset of organ formation, hyperplasia, and increased auxin transport. Of note, plants (Arabidopsis and tomato) overexpressing this H⁺-PPase develop extremely robust root systems. In contrast, avp1-1 null mutants have severely disrupted root and shoot development and reduced auxin transport. We conclude that AVP1 plays an important role in organ development through facilitating the auxin fluxes that regulate organogenesis. Transgenic alterations such as those found in AVP1OX plants, where the up-regulation of a single gene results in enhanced capacity to withstand abiotic stress (salinity and drought), enhanced biomass production, and enhanced nutrient uptake ability, will certainly have a positive impact on agricultural production, helping to meet the challenge of world hunger. Additionally, this research will shed light on our understanding of key chemiosmotic mechanisms involved in the regulation of plant growth and development.
P 4.23 - The metabolic profiling of osmolyte accumulating mutants, transgenics and extremophile relatives of Arabidopsis thaliana under osmotic or salt stress conditions

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Metabolic profiling consisting on simultaneous quantification of most compounds belonging to restricted chemical families, mainly amino acids, amines, organic acids and carbohydrates has been performed with different genetic backgrounds to explore regulatory effects of salt stress and compatible solute accumulation in Arabidopsis thaliana and Thellungiella halophila, a relative extremophile. Processing data with suitable statistical tools and corresponding hierarchical cluster analysis, principal component analysis and metabolite pair-wise correlation analysis have provided information about adjustments and disturbances assessed to metabolic networks in proline or glycine betaine accumulating genotypes growing or not under salt stress conditions. Thus several lines were under focus, the Arabidopsis cold tolerant mutant Eskimo which constitutively accumulates proline, transgenic Arabidopsis lines expressing the CodA gene for choline oxidase and producing glycine betaine and T. halophila a cold and salt tolerant species closely related to Arabidopsis and described as a proline accumulating system. Metabolic profiles provided accurate phenotypic descriptions of transgenic lines or single gene mutants and pointed out differentiated metabolic networks reconfiguration depending on the nature of the accumulated osmolyte and the imposition of stressing or non-stressing conditions. Regulating impact of proline (the natural osmolyte of A. thaliana) and glycine betaine (the heterologous osmolyte) could be compared. Moreover, biochemical responses induced by salt treatments in A. thaliana and T. halophila could be clearly distinguished providing some indications about stress responsive and stress tolerant metabolic targets.

P 4.24 - The effect of drought stresses on different sugar beet genotypes (Beta vulgaris L.)

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Sugar beet (Beta vulgaris L.) is considered as the second most important sugar crop in Egypt. Beta vulgaris L. var. Saccharifera (altissima) belongs to the genus Beta family Chenopodiaceae. The potential usefulness of somaclonal variation for plant improvement first became apparent in many crop plants, including sugar beet. The interest in the effect of drought stress on plant results mainly from the need to better understand the problems to which economically important crops are exposed where water is a limiting factor. On the basis of in vivo and in vitro selection, testing the effect of drought stresses by using polyethylene glycol (PEG) to determine the tolerance of different sugar beet genotypes was carried out. The DNA content and isozymes patterns were performed to characterize the effect of PEG.
**P 4.25 - Effects of water stress and stress recovery on the legume model plant Medicago truncatula cv. Jemalong**

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*Medicago truncatula* is the main model for the study of legumes’ biology. We have been using genetic engineering to express genes responding to water deficit in this plant. However, the physiology of this species has been scarcely studied, including the aspects related with response to drought. This work is a contribution for the knowledge of the physiological behaviour of this species under water deficit. Plants were grown in a controlled environment chamber and stress was induced by withdrawal of watering during seven days. Pots were then re-watered and the same parameters were measured for more three days, except when leaves showed total senescence. Partial or total plant recovery was possible when field soil capacity did not went under 40%, while when lower values were reach no recovery was generally obtained. The leaf relative water content (RWC) decreased from 80 to 35% under stress and recovered to 80% after re-watering. Psychrometric water potential decreased from -2.0MPa to -9.0MPa. Infra red gas analysis showed that net photosynthesis decreased from 25 to four recovering to 26 μmolCO₂m⁻²s⁻¹ and the transpiration rate decreased from five to two recovering to six mmolH₂O m⁻²s⁻¹. Modulated fluorometry indicated that the maximal photochemical efficiency of PSII decreased from 0.82 to 0.65 and recovered to values above 0.8. The electron transport rate decreased from 160 to 60 recovering to 145 molm⁻²s⁻¹. The photochemical quenching decreased from 0.7 to 0.35 and recovered to 0.66. The non-photochemical quenching increased from 0.6 to 0.75 recovering to 0.62.

**P 4.26 - Targeted metabolite profiling uncovers biochemical links with drought adaptation in the genus Eucalyptus**

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The genus *Eucalyptus* encompasses some 700 species constituting the major forest stratum across much of the Australian continent. Eucalypts tolerate environments with as little as 250 mm annual rainfall and whilst it has been suggested that the distribution of *Eucalyptus* species is particularly dependant on the availability of water, there has been limited research into the chemical attributes that confer such tolerance. Substantial evidence for the roles of cyclic sugar alcohols (cyclitols) as stress metabolites has been gleaned from investigations in both tree and herbaceous plant species. The proposed roles of cyclitols in plant tissues, and their close association with primary metabolism, suggest that cyclitols are well suited to the amelioration of stressful conditions. Using a targeted metabolite profiling approach, we have identified contrasting biochemical responses to water deficit among eucalypt species. We have shown that substantial concentration of the cyclitol ‘quercitol’, plays a significant role in the regulation of osmotic potential in leaf, stem and root tissues of *Eucalyptus* species originating from arid environments. Additional metabolite profiling, encompassing some 279 eucalypt species, has also shown that the accumulation of quercitol is a quantitative yet discrete biochemical link with eucalypt taxonomy and evolution. This investigation represents the first correlation of plant biochemistry with the adaptation of eucalypts to arid environments. Further understanding of these mechanisms will aid efforts towards land rehabilitation and sustainability in arid regions.
P 4.27 - The area of dispersal affects carbon isotope discrimination of Mediterranean durum wheat landraces

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This research was undertaken to investigate whether the way of dispersal of durum wheat across the Mediterranean basin affected carbon isotope discrimination (Δ) and its relationships with grain yield. In a previous work, 63 durum wheat landraces were genetically characterized as being dispersed by the north or the south of the Mediterranean basin. From them, the twelve landraces - 6 from the north and 6 from the south - that maximized the genetic diversity were sown in two rainfed environments. Differences between groups of dispersal were detected for yield and Δ, being the higher values reached by northern genotypes (15.2% and 14.9% for the northern and southern groups, respectively). The relationships between yield and Δ depended on the group of dispersal and the environment. In the lowest yielding environment (2.28 t/ha), none significant relationship between these two traits was attained, while in the most productive environment (3.32 t/ha) a negative association between Δ and yield was obtained for northern landraces (R² = 0.85, P < 0.01), but positive for southern ones (R² = 0.70, P < 0.05). These results are discussed in the context of the environments prevalent in the areas of dispersal.

P 4.28 - Cytochrome b$_{561}$ and ascorbate oxidase as components for a novel redox chain in leaves of wild watermelon: does it contribute to the dissipation of excess light energy?

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Ascorbate plays critical roles such as a redox buffer and an antioxidant. Higher plant cytochrome b$_{561}$ mediates trans-membrane electron transfer by oxidizing ascorbate on one side of the membrane and reducing monodehydroascorbate on the other side, although its physiological function is unclear. In leaves of wild watermelon (Citrullus lanatus L.) grown at a high light intensity, the CLb561A protein, a member of cytochrome b$_{561}$ family, was accumulated by drought treatment. To our knowledge, induction of cyt b$_{561}$ by stress was unique to wild watermelon. Since the CLb561A protein was not detected in leaves grown at a low light intensity even after drought treatment, CLb561A was correlated with excess light energy. Subcellular fractionation analysis indicated that the CLb561A protein was localized in the plasma membrane. These observations implied that the electron flow from the cytosol to the apoplastic side was enlarged by the CLb561A protein under stress conditions. Indeed, the electron flux from cytosol to apoplastic space estimated using leaf segments and an electron accepter was increased in stressed leaves. We also found that the activity of ascorbate oxidase, which catalyzes the oxidation of ascorbate in the apoplastic space, was unprecedentedly high in leaves grown at high light intensities. Taken together, it is suggested that fortification of the cyt b$_{561}$ induces the large electron flow from the cytosol to the apoplastic space in the ascorbate oxidase redox chain, which may function as a device for dissipation of excess energy in wild watermelon leaves.
**P 4.29 - Hormonal balance involved in amino acid metabolism adjustments under osmotic stress in canola**

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Plant aminoacids metabolism has been shown to be highly responsive to numerous physiological and developmental situations. This property may be illustrated by spectacular proline accumulations induced by water deficit related constraints in a wide range of plant species, and by glutamine increases frequently described on senescence induction. In both examples, the described disorders are related to induced proteolysis activities and consecutive amino acids release. They appear to be relevant to some compulsory aminoacid metabolism adjustment, which could lead to the preferential generation of a compatible form of aminoacid like proline or to the synthesis of a transportable form of N-compounds like glutamine, depending on the physiological context. Moreover, the metabolism of glutamate, from which proline and glutamine are derived, appears to be the target of a specific control following stress or senescence induced aminoacid metabolism imbalance. To explore some keys of the regulation of the glutamate pathway in canola leaf tissues, we studied the effects of two phytohormones respectively involved in stress and senescence responses: the abscissic acid (ABA) and methyl-jasmonic acid (MJ). Their exogenous supply have striking opposite effects at aminoacid distribution and gene expression levels. ABA and/or stress induced proline accumulation is severely reversed by MJ, in relation to similar P5CS (pyrroline-5-carboxylate synthetase) gene regulation; MJ increases glutamine levels, in association with stimulation of PDH (proline deshydrogenase) gene expression. Conversely, regulation of the glutamine synthetase genes are not clearly involved. These results show an ABA and MJ control of orientation of glutamate fluxes in antagonistic ways.

**P 4.30 - Changes in polyamine concentration in leaf, ear tip and silk tissues of maize under water-stress**

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Polyamines such as putrescine, spermidine and spermine are low molecular mass poly-cations found in all living organisms. In plants, these compounds have been implicated in a wide range of biological processes, including growth, development and abiotic stress responses. To investigate changes in polyamine levels in response to water stress conditions in maize, silk, leaf and ear tip tissues were harvested in the field from two parental lines Ac7643S5 (P1, drought tolerant) c7729/TZSRWS5 (P2, drought susceptible), and three contrasting genotypes from both tolerant and susceptible tails of a segregating population developed from those two lines. Although not always significant, there was a clear tendency of polyamine accumulation under stress versus well-watered conditions for spermine in leaf tissue and for putrescine in silk in the tolerant and sensitive descendant. In addition, when studying changes over time, there was a tendency for all tissues to increase polyamine and this increase was more significant in tolerant compared to susceptible genotypes. Independent of the treatment, a significant difference in the level of the three polyamines was found across the three target tissues, with spermine being largely in excess in leaf tissue while putrescine was most abundant in the silks. In ear tip tissue there were relatively higher concentrations of spermidine than either other polyamines in this tissue. This clearly indicates that polyamine regulation in maize is tissue specific and that the biological function of those polyamines in response to stress can vary depending on the nature of the organ in question (e.g. source versus, sink).
P 4.31 - Analysis of the chlorophyll a fluorescence transient OJIP during drought stress and re-watering of barley cultivars (Hordeum vulgare L.)

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The main objective of this study was to compare the effects of drought and re-watering treatments on different varieties of barley plants. Five varieties obtained from the National Institute of Agricultural Research (INRA) of Morocco and five landrace populations collected at five localities in the south of Morocco were used. After two weeks of growth, drought stress was initiated by withholding water for a period of two weeks. Then the plants were re-watered for 1 week. The level of drought stress reached one week without watering was referred to as moderate drought and the level reached after two weeks was referred to as severe drought. The polyphasic fluorescence transient (OJIP) was used to evaluate photosystem II (PS II) criteria. The relative water content (RWC) decreased during drought stress, it varied between 61 and 78.2% at the end of the drought period. During the recovery period RWC increased and varied between 87.5 and 94.1%. We observed that drought and re-watering treatments had little effect on the relative ratio FV/FM confirming a high stability of the quantum yield of primary photochemistry of PS II. The photosynthetic performance index (PI) as a measure of plant performance, revealed differences between varieties as a consequence of drought stress and re-watering. Large differences in the responses of the ten varieties to drought stress could successfully be established by using a novel parameter, the so-called drought factor index (DFI). Ranking based on DFI is proposed to be a good way to screen for drought stress tolerance.

P 4.32 - Possible plant mitochondria involvement in cell adaptation to drought stress

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Although plant cell bioenergetics is strongly affected by abiotic stresses, the mitochondrial metabolism under stress is still largely unknown. Mitochondria are involved in photorespiratory cycle, proline and ascorbate metabolisms and, interestingly, may control reactive oxygen species (ROS) generation by means of some energy dissipative systems. Therefore, mitochondria may play a central role in cell adaptation to several abiotic stresses, which are known to induce oxidative stress at cellular level. In particular, plant mitochondria possess three energy dissipative systems: the Alternative Oxidase (AO), the Plant Uncoupling Mitochondrial Protein (PUMP) and the ATP-sensitive Plant mitochondrial Potassium Channel (PmiKATP), this last discovered by us few years ago. We showed that PmiKATP, PUMP and AO are able to dampen mitochondrial ROS production; moreover, PmiKATP and PUMP are surprisingly activated by ROS. This was found to occur both in mitochondria from control seedlings and in mitochondria from hyperosmotic-stressed seedlings. Therefore, the hypothesis of a “feed-back” mechanism operating under hyperosmotic/ oxidative stress conditions was validated: stress conditions induce an increase in mitochondrial ROS production; ROS activate PmiKATP and PUMP that, in turn, dissipate the mitochondrial membrane potential, thus inhibiting further large scale ROS production. Another important point is the chloroplasts/ cytosol/ mitochondria cooperation under stress to modulate cell redox homeostasis. For example, durum wheat mitochondria may act against chloroplast/ cytosol overreduction: the malate/ oxaloacetate antiporter and the rotenone-insensitive external NADH DH allow cytosolic NAD(P)H oxidation; this occurs without high ROS production due to AO activation under stress. The possible involvement of these mechanisms in cell adaptation to drought stress is discussed.
P 4.33 - Detection of early reactions of Lupinus albus plants to water deficit

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The study of early effects of water deficit (WD) in plants that can withstand severe stress, such as Lupinus albus, can give important information concerning WD tolerance in crop plants. In order to establish when the WD started to act on our biological system, several parameters, ranging from the soil and the plant water status to sugar and ABA concentrations were evaluated in a time course experiment. Our data show that three to four days after withholding water (DAW), leaf \(\Psi_{pd}\) and conductance were reduced by 20 and 60%, respectively, reflecting a decrease in the soil water content (by 30%). Although the relative water content (RWC) of the several organs analysed did not reveal any significant alteration, we detected modifications in sugars (fructose, glucose, sucrose) and starch at 3-4 DAW in the roots. These results suggest that WD was most probably installed at 3-4 DAW. However, the alteration in the sugar pattern of the root was not accompanied by significant changes in the ABA levels.

P 4.34 - Electron flows in barley chloroplast under dehydration

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The knowledge about causes of photosynthesis inhibition under dehydration is contradictory. The water deficit can restricted the photosynthetic activity by both suppression of Calvin cycle enzymes activity and inhibition of linear electron flow in chloroplast. The aim of our work is investigation of electron flows in chloroplasts under dehydration of barley seedlings. Water deficit (45 h on the 6% PEG 6000 solution) reduced the rate of potassium ferricyanide recovery in seven-day-old barley leaves. Photochemical activity of photosystem II (PS II) which was determined as effective and potential quantum yield of PS II was not changed by dehydration. The state of primary and secondary quinone acceptors of PS II was defined by means of chlorophyll fluorescence induction. Dehydration decreased the amplitudes of fast and middle components and enhanced the amplitude of slow component of the dark relaxation of variable chlorophyll fluorescence. Because the slowest component (life-time of several seconds) is suggested to represent a minor population of inactive PS II centers, the fast component (half-time of 5-10 ms) shows rapid oxidation of QA- during electron flow to plastoquinone pool, the middle component of \(F_v\) dark relaxation (50-100 ms) is an indication of restricted electron transfer from QA- to a largely reduced plastoquinone pool, and formation of the slow component (500-700 ms) occurs only after the plastoquinone pool has become fully reduced and is caused by recombination between QA- and the S2 state of the water-splitting complex, obtained data indicated that dehydration inhibited the linear electron flow by excessive reduction of the plastoquinone pool. Increase of the reduced plastoquinone amount was caused by the raise of lipid bilayer viscosity and lowering of plastoquinone lateral diffusion rate.
P 4.35 - Proteomic analysis of drought responsiveness in rice peduncles

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Panicle emergence in rice is affected when drought coincides with the flowering period. This occurs due to the failure of elongation of the peduncle, the uppermost internode of the stem. During drought stress at flowering, the peduncle elongation rate falls from about 6 cm per day to zero. When plants are re-watered after several days of drought stress, peduncle elongation may resume approximately at the original rate but failed to go to completion as in IR64 or may halt completely as in Moroberekan. We used proteomics to examine gene expression in peduncles in response to drought and rewatering. 2D-PAGE analysis of proteins from peduncle tissue detected over 450 proteins, of which about 22 were significantly affected by drought stress. The effect of drought was largely reversed by re-watering for 10 of these proteins, including actin depolymerizing factor (ADF5), putative cold shock protein-1, a Group 1 late embryogenesis associated (LEA) protein, and glutathione-dependent dehydroascorbate reductase (up-regulated by stress) and S-adenosyl methionine synthetase (3 forms), a homologue of the microtubule-associated translationally controlled tumour protein, a Bet VI allergen-like protein, putative L7a ribosomal protein, and nuclear transport factor (down-regulated by stress). However, some proteins showed irreversible responses to stress. One protein that showed reversible induction by drought stress in IR64 but irreversible induction in Moroberekan was member of Group 6 of the LEA protein family. These results highlight the importance of rapid and specific protein degradation in drought responsiveness and recovery from drought. Further it was also observed that ABA levels in peduncles increased markedly in response to drought but returned to normal on re-watering. ABA breakdown via 8'-hydroxylation was studied at the enzymatic and transcript levels which revealed that the transcript levels of cytochrome P450 CY P707A5 were closely correlated with changes in ABA levels in peduncles. CY P707A5 is the rice P450 most closely related to the Arabidopsis P450s associated with ABA 8'-hydroxylase activity.

P 4.36 - The identification of salt and drought tolerance candidate genes: a comparative proteomics approach

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Proteomic analysis offers a new approach to discovering the genes and pathways that are crucial for stress responsiveness and tolerance. We have applied a comparative proteomics approach to study salt and drought responsiveness in plants which differ in their response and tolerance mechanisms. We studied physiological and proteome response of rice, wheat, sugar beet, and Suaeda aegyptiaca under salt and/ or drought stresses using two dimensional electrophoresis coupled with mass spectrometry. We identified several tolerance candidate proteins and pathways involved in redox regulation, protein synthesis and folding, oxidative stress tolerance, lignification, cytoskeleton remodeling, osmolyte production, signal transduction, and iron homeostasis. Comparative proteome analysis of these species will be discussed and interpreted in terms of the common and different mechanisms involved in response of plants to salinity and drought stresses. We discuss strategies for maximizing the success of such applications.
P 4.37 - Genetic control and performance of doubled haploid lines for drought resistance in wheat

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The objective of this research work was to evaluate the agronomical and physiological performance of two spring wheat cultivars and their doubled haploid lines (DH), to assess the understanding of the relation between the studied traits and their use for drought resistance purposes. Parental lines 'Pavon' and 'Sieteserros' (susceptible and resistance to drought, respectively), as well as DH lines derived from their F1 progenies were used in this study. The experimental design was a complete-randomised block design with three replications which was realized in a controlled greenhouse. Relative water content (RWC), leaf water potential (LWP), rate of water loss (RWL), which are considered as indicators for drought resistance as well as some agronomic traits were evaluated in parental lines and their 60 doubled haploids (DH). Significant differences were observed among the DH lines for all studied traits. Genetic gain as the difference between the mean of 10% selected doubled haploid lines (DH) and the best parent was significant for most of the traits. Heritability was high for RWC and LWP (64.85 and 51.04%), whereas RWL had a lower heritability (37.02%). Agronomic traits presented high heritabilities (more than 50%). Genetic correlations showed an association of low RWC and low LWP (in positive values), with high yield and most of its related traits; while high leaf water potential was associated with thousand grain weight and harvest index. Multivariate analysis identified some genotypes associating high RWC, low LWP and good yield. The results are discussed for resistance to drought.

P 4.38 - Peptidyl prolyl cis-trans isomerase activity and drought tolerance

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Drought stress-induced changes in peptidyl prolyl cis-trans isomerase (PPIase) activity were studied in drought tolerant (ICSV-272, RSLG-272, M35-1, CSV-14R) and susceptible (SPRU-94008B and CSV-216) cultivars of sorghum (Sorghum bicolor). Drought stress was imposed by withholding water supply to the pot grown plants at 30 DAS. The leaves were harvested and water potential measured. The PPIase activity was estimated in the protein extracts after ethanol precipitation. Significant water stress-induced increase in leaf PPIase activity was observed only in drought tolerant cultivars RSLG-272, CSV-14R and M35-1 whereas, in the drought-susceptible cultivar the PPIase activity decreased in response to drought. It was concluded that the leaf PPIase activity has the potential of being used as a marker for water stress tolerance in sorghum.
The ability of the plant root system to extract water and nutrients from the soil is one of the most important components of drought tolerance. Plants having thick and longer roots can colonize water effectively from the deeper soil than those with a shallow root system. This helps in maintaining good plant water potential, which has a demonstrated positive effect on yield under stress.

Some of the upland grown rice varieties develop longer roots when subjected to water stress. In order to understand this mechanism, Moroberecan, a deep-rooted upland Japonica rice cultivar and IR64, a shallow rooted lowland Indica rice cultivar were grown in polyvinyl chloride pipes with Turface as a growing medium and Yoshida’s solution as a nutrient source. Water was withheld after 35 days and roots were sampled on 7th, 13th, 20th and 28th day after withholding water. When subjected to water stress, the root length of Moroberecan was significantly longer than that of IR64. Root RNA from two time points, seven-day and 13-day and two treatments namely, well-watered and water stress, were used to carry out the expression studies. Expression analysis was carried out at the Beijing Genome Institute (BGI). A whole genome (Indica) microarray containing 62K 70mer, oligo nucleotide gene specific probes was used. Hybridization was carried out between contrasting water treatments of seven-day- and 13-day-time points for both the varieties. The 7-day and 13-day exhibited a different set of genes expressed between and within varieties, and between the stress and well-watered treatments. Root RNA was used to carry out RT-PCR for hormone synthesis and responsive genes like Auxin, Ethylene, Gibberellins, cytokinins and ABA from drought stressed panicle cDNA library. Out of 11 hormone synthesis and responsive gene primer pairs tested on the root RNA, only ABI5 showed differential regulation between water stressed Moroberecan and IR64 roots. ABI5 primers amplified the gene in Moroberecan, the gene was absent in IR64. RT-PCR was carried out with primers designed to amplify the Aquaporin gene on chromosome 2. A major QTL is located coinciding the Aquaporin (NOD26-like membrane integral protein) gene on chromosome 2. RT-PCR amplified the Aquaporin gene from water stressed IR64 roots but failed to amplify in Moroberecan.

Physiological and biochemical traits for screening of DT lines

Based and physiological and biochemical parameters, certain early detection tools like testing of germplasm in PEG-6000 (-10 bar), radicle/plumule ratio and seed storage protein profile (SDS-PAGE) were established as important traits for seedling stage drought tolerance. Season screening (under high temp. > 400 °C) also help in donors selection. Higher grain sterility was observed in irrigated and rainfed environments in all lines/cultivars mainly due to severity due to stress and repeatable spell of drought which reduce the photosynthetic area (high degree of leaf rolling) and poor pollen fertilization, further wet season, reproductive stage (21 d drought spell) resulted in inconsistent/stable yield and sterility differences among selected lines under manage stress. Here, RWC and sterility indicated very good relationship with grain yield in water stressed environment. Early varieties showed more reduction in yield and higher sterility percent than medium duration varieties. Mobilization efficiency in terms of -CHO content and biomass production indicated a very good correlation for stable grain yield in stressed environment. High CHO content during grain-filling stage negated the sterility occurrence in panicles because of high RWC. Higher CHO content favoured RWC, maintenance in DT lines over susceptible lines. Apparent translocation rate and panicle RWC could be considered good traits for screening of DT lines in target drought environment environments.
P 4.41 - Durum wheat (Triticum durum Desf) awns: anatomy and role in the determination of grain yield under drought conditions in Mediterranean zone

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Awns can play a major role in determining grain yields and resisting to drought. Indeed, all varieties which were developed in drought-prove zones have awns. In the south Mediterranean zone, most cultivated cereals have a developed awns with the exception of the beard wheat which is cultivated only in humid areas. Whereas, studies interested in this subject are not numerous. In this work, we studied the role of durum wheat awns in the determination of grain yield under irrigation and water deficit conditions. Three varieties (INRAT69, Razzak and Duriac) were studied under two water regimes (irrigated and no irrigated). The awns of plants were cut off. They were shown to play a major role in the elaboration of grain yield under water deficit. The role of this organ is more important in grains filling as defined by the weight of kernel per ear and the weight of thousand kernels than in determining the number of kernels by ear. We were interested also in this work to study the anatomy of durum wheat awns and the variation of stomatal density within the water regime. This study showed the presence of three conducting elements in each part of awns. Thus, photosynthate of awns will be transferred easily to grains. It is, therefore, important to protect durum wheat plants against diseases that may attack awns towards the end of development cycle.

P 4.42 - Using infrared thermography to study the CO₂ and ABA signalling pathways in Arabidopsis

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Stomata are small pores on leaf surfaces that regulate gas exchange. When stomata are closed leaf temperature is higher than when they open. Leaf temperature can be recorded using infrared thermal imaging cameras. A screen of a population of EMS mutagenized Arabidopsis plants identified, after drought, mutants impaired in the ABA signalling pathway. The aim of this project is to use infrared thermal imaging to identify mutants that have lesions in the stomatal response to elevated CO₂.

First we characterised the stomatal response to elevated CO₂ of wild type Arabidopsis plants. We built a Teflon covered chamber that allows plants to be imaged from the outside. Once plants are inside the chamber we recorded thermal images during a period at ambient [CO₂] (360ppm) followed by a period at elevated [CO₂] (up to 1400ppm). Results showed that at high [CO₂] leaf temperature of 28 days old Col-0 plants increased of 0.9-2.3°C. We screened 18,000 EMS plants comparing leaf temperature at 360ppm and 1400ppm [CO₂]. Mutants that did not show the characteristic response to high CO₂ were selected. Ler and Col-2 plants showed a characteristic response to elevated by increasing leaf temperature, the abi1, abi2, and ost1 mutants showed a reduced response, while abi1-1 and abi2-1 did not respond.
**P 4.43 - Regulation of citrulline accumulation in wild watermelon under drought in the presence of strong light**

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Citrulline is an efficient hydroxyl radical scavenger which accumulates at a concentration of up to 30 mM in the leaves of wild watermelon during drought/strong light stresses. In plants, citrulline biosynthetic pathway is composed of seven enzymes, which are N-acetylglutamate synthase (AGS), N-acetylglutamate kinase (AGK), N-acetylglutamate semialdehyde reductase, N-acetylornithine aminotransferase, glutamate N-acetyltransferase (GAT), carbamoyl phosphate synthetase (CPS), and ornithine carbamoyltransferase. However, how these enzymes are regulated for massive accumulation of citrulline in wild watermelon remains unclear. In this study, to understand mechanism of citrulline accumulation, we analyze the effects of drought/strong light stress on the activities of these seven enzymes. First, we determined the changes in activities of the seven enzymes in wild watermelon leaves during drought. The activities of the first and second enzymes in the pathway, AGS and AGK, and the enzyme forming carbamoyl carrier, CPS, increased approximately 7-, 7-, and 3-fold, respectively, whereas the activities of other enzymes did not change significantly during drought. Furthermore, GAT, which simultaneously catalyzes the first and fifth reactions, exhibit high thermostability as well as insensitivity to feedback inhibition by citrulline or arginine at physiologically relevant high concentrations. These results suggest that citrulline biosynthesis is triggered by the increase in the influx of glutamate the carbon skeleton and the carbamoyl moiety into the pathway and unique properties of the enzymes contribute to the massive accumulation of citrulline under drought/strong-light conditions.

**P 4.44 - Regulation of carbohydrate metabolism in maize plants under water stress**

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The aim of the project is the characterization of carbohydrate metabolism in maize cobs and growing silks during water stress. Different water-stress tolerant parental lines and RILs have been analysed under managed drought experiments in the field. Drought leads to a delay of female organ development in comparison to tassel growth, thus increasing the anthesis-silking interval. Flowering time desynchronisation leads then to decreased grain yield. We have manipulated the carbon status of the plant through organ removal or feeding experiments. In those experiments we studied the rate of silk growth, embryo development and grain filling. Detasseling leads to increased yield, whereas leaf area reduction limits photosynthetic production of assimilates. The results suggest that silk growth is dependent on phloem pressure and can be maintained by the usage of internal carbon stores in the cob rachis. We are trying to identify and characterize the genetic loci that control the rate of silk growth in maize plants. Currently we are focusing on a candidate gene approach of carbohydrate enzymes for developing molecular markers within the quantitative trait loci for water stress.
P 4.45 - Multivariable approach to monitoring stress in cork oak stands

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It is highly desirable to combine all sources of information about plant stress to find patterns of plant response to drought conditions. We researched many variables within a set of 15-year-old Quercus suber L. trees growing under a Mediterranean climate during the summer periods of 2003 and 2004. The variables include: leaf water potential, leaf temperature, chlorophyll fluorescence parameters (yield, photochemical quenching and non-photochemical quenching), pigment content, gas exchange (photosynthesis and stomatal conductance). We analysed patterns for each variable both over time and spatially. This included analysing the distribution of frequencies for some of the variables. Leaf temperature showed a similar pattern along the summer to air temperature. During summer 2003, there was a difference in stomatal conductance pattern of response at 10 AM and 2 PM, probably due to higher relative humidity of air at 10 AM. Leaf water potential, stomatal conductance and photosynthetic CO₂ assimilation show similar patterns of response during summer. Variability between plants in leaf water potential increased along the season. This trend was not seen in the index derived from our thermal data.

P 4.46 - A study of responses to water-stress applied uniformly or asymmetrically to part of the root systems of transgenic and untransformed tomato plants

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Over-expression of transgenes encoding 9-cis-epoxycarotenoid dioxygenase (NCED), a key regulatory enzyme controlling abscisic acid (ABA) biosynthesis, has resulted in elevated ABA levels. A study on the growth and physiological responses of 'high ABA' transformants of tomato (Lycopersicon esculentum), together with their wild-type (Wt) counterpart, was conducted. Plants were exposed to a progressive water-stress treatment by rationing the water supply and also by growing half of them on an irrigation system known as partial root-zone drying (PRD). PRD was based on the idea of a split root system in which one half of the root-zone was irrigated while the remaining half was left to dry. This system allows the total demand for water of the plant to be met through the wet side alone whilst at the same time, deliberate withholding of irrigation water on the other side of the root system meant that plants were subjected to the physiological influence of water-stress related signals. Studies showed that 'high ABA' transgenic plants fared better under conditions of limited water availability compared to Wt plants. The growth of 'high ABA' transformants surpassed that of the Wt plants despite being much smaller at the onset of the trial. Transgenic plants also displayed a lower stomatal conductance during periods of maximal evaporative demand and were therefore able to minimise water loss through transpiration. The reduction in stomatal conductance observed reflects the plant's capacity to retain water in the soil and therefore perform better over an extended period of water rationing. Genetic manipulation of stomatal responses appeared to be more effective in conserving water than environmental treatments involving PRD.
ABA is a phytohormone that plays an essential role in drought response in plants. A lot of drought inducible genes are regulated by ABA signal and production. There are 6 genes encoding a 9cis-epoxycarotenoid dioxygenase (NCED), a key enzyme involved in the biosynthesis of ABA in Arabidopsis genome. In AtNCED genes, NCED3 was required for drought inducible ABA accumulation that is essential for drought tolerance (Iuchi et al. 2001). In the present study, we analyzed transcriptome and metabolome profiling of NCED3 knockout mutant (nced3-2) under drought stress. Metabolite profiling using LC/MS, GC/MS and CE/MS of wild-type plants showed an accumulation of various types of amino acid, small organic compounds, sugar and flavonoids in response to drought stress. In contrast to the wild-type plants, drought inducible accumulation of aromatic amino acids, branch-chain amino acids, proline, polyamines and flavonoids were reduced in the nced3-2. Microarray analysis also showed that several metabolic pathways reduced in nced3-2. Based on these experiment, we will discuss the biological function of ABA involved in metabolic networks of plant in drought stress response.
P 4.48 - Study on the correlation between carbon stable isotope discrimination and spring wheat grain yield

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Northwest China is one of the areas where there is the most shortage of water and is also one of the poorest regions in China. Wheat is a main crop in this region. Therefore, enhancing its yield and drought-tolerance is the key solution for food security of this region. Thirty-two spring wheat varieties, which were collected from crop breeding organizations in Northwest China, were studied in this experiment in 2004. They were tested both in the Ningxia rain-fed areas where Guyuan and Pengyang, which had precipitations from 172.5 to 198 mm, and in the limited irrigation areas, where Yingchang and Huinong, which had precipitations from 42 to 50 mm during whole growth period, with 1500 m³/hm² irrigation in the tillering stage. The research items were: grain production, WUE of single leaf, carbon isotope discrimination (δ) of flag leaf and grain in different ecological regions and the correlation with among them. The result showed that the carbon isotope discrimination (δ) both of leaves and grains was various obviously, depended on genotype differences among the thirty-two wheat varieties, either under rain-fed condition, or under limited condition. Under rain-fed condition, the values of grain had a variation range from 16.06 to 17.27%, and the range from 18.41 to 19.38% for leaves’ values. The grain yield had a range from 1.1 t/hm² to 5.1 t/hm². Meanwhile, under limited irrigation condition, the values of grain had a range from 16.82 to 19.01% and the range from 18.41 to 20.03% for leaves’ values. The grain yield had a range from 2.8 t/hm² to 13.5 t/hm². Values both of grains and leaves correlated positively with yield (r = 0.421 ~ 0.442, P 0.05 = 0.349) and showed weak negative correlation with transpiration efficiency under rain-fed condition. While, under limited irrigation condition, there was weak negative correlation between grains’ value and grain yield, as well as between leaves’ value and grain yield (r = -0.07, r = -0.08). The statistics with the mean of all genotypes, under limited and rain-fed conditions, displayed positive correlation between and grain yield (r = 0.38~0.43 P < 0.05). Our experiment also indicated that higher yield wheat varieties had higher values. Furthermore, we found that the varieties bred under irrigation condition had higher values. Meanwhile, the varieties bred under rain-fed condition had lower values. Above results still need further experiments to check because the results were one year results for 2004 only.
P 4.49 - Adaptation to drought stress among spring wheat cultivars of different decades in semi-arid China. I: Responses of cultivars to drying soil under the pot-culture condition

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Pot-culture experiment was conducted in a rain shelter to compare the responses of 8 spring wheat cultivars of decades to drying soil. The potential for survival days (SD), foliar dehydration and yield stability was determined under standardized soil and atmospheric conditions. Dehydration tolerance was operationally defined as lethal leaf water potential (LLWP): LLWP of the last remaining leaves surviving a continuous, lethal soil drying episode. SD was operationally judged by the days to reach leaf water content on which permanent wilting occurred was determined by repeated measures on the same plants. Monkhead and Jinby, two ‘old’ cultivars, were the most sensitive to drought stress, having the highest LLWP of –3.05 and –2.77 MPa, and the least number of 8.9 and 10.2 survival days at all stages. Their maintenance rates of shoot biomass (MRSB) were also lower than those of six non-old cultivars. Plateau602 and Longhun8139, (recent cultivars), and Longhun8275 (modern cultivars) withstood the most drought tolerance, with LLWP of -3.98 MPa or below, and the most SD (more than 14 days). Coincidently, these three cultivars had the highest MRSB by drought. LLWP and SD of other intermediate species were: Dingxi24 (-3.38 MPa and about 13 survival days, recent cultivars), 021-128 (-3.52 MPa and about 13 days) and 92-46 (-3.69 MPa and about 12 days, modern cultivars). LLWP and SD were significantly correlated with MRSB. This means that with the anti-drought breeding development, spring wheat would evolve in the direction of a strong drought tolerance rather than drought avoidance in the semi-arid area.

P 4.50 - Leaf senescence-inducible expression of isopentenyl transferase in cassava rendering it resistant to drought stress

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It is well-known that cassava (Manihot esculenta Crantz) could stand prolonged abiotic stress and survives by shedding its leaves. Cytokinins exhibit antisenescence and drought resistance properties. Expression of the isopentenyl transferase (ipt) gene, which encodes a key enzyme for cytokinin biosynthesis, from Agrobacterium tumefaciens under control of the senescence-induced SAG12 promoter from Arabidopsis should lead to delayed cassava leaf senescence via an autoregulatory senescence inhibition system. We have transformed cassava plants with the ipt gene under control of the SAG12 promoter. The insertion of the SAG12-ipt cassette has been confirmed in seven cassava plant lines by PCR and Southern analyses. in five of these low expressions of ipt in mature leaves by RT-PCR analysis could be detected. After dark-induced senescence treatment of mature leaves from both in vitro and greenhouse-grown plants, significant stay-greenness and repressed chlorophyll degradation were observed in the transgenic line 529-28 compared to wild-type. The line also displayed resistant to leaf senescence after drought treatment. Only 10% leaves of 529-28 become senescent in comparison with 50% of wild-type and 20% of line 529-48 from 3-month-old plants. The expression of ipt was increased in the old leaves of drought-treated 529-28 lines. During the development of transgenic plants, the decrease in chlorophyll, total protein, and Rubisco content in mature leaves was repressed. Interestingly, the transgenic plants also showed an early storage root bulking in comparison with wild-type plants. Evaluation of the yield of leaves and storage roots as well as drought resistance level will be field-trialed at CIAT, Colombia.
P 4.51 - ABA-inducible maize transcription factors function in regulation of ROS homeostasis and tolerance to multiple abiotic stresses

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Reactive oxygen species (ROS) can act both as signaling and toxic molecules in plant responses to abiotic stresses, thus the production and scavenging of ROS must be tightly controlled in plants. Increasing evidence revealed that plant hormone ABA as a stress signal regulates the expression of antioxidant genes encoding SOD, CAT and APX. However, the molecular mechanism underlying the regulation of these genes by ABA remains largely unknown. By screening a maize cDNA library via yeast one-hybrid system using the ABA-responsive element (ABRE) of maize Cat1 promoter as a bait, seven genes have been cloned encoding transcription factors belonging to bZIP and bHLH family, respectively. In vitro and in vivo results show that two of the transcription factors, namely ABP2 and ABP9, can specifically bind to ABRE motif and activate the expression of downstream reporter genes. Expression profiles in maize indicate that both ABP2 and ABP9 can be induced by ABA and stress conditions like drought, high salt and H$_2$O$_2$. Over-expression of ABP2/ABP9 resulted in enhanced tolerance to multiple abiotic stresses, significantly reduced cellular level of ROS and activation of many defense genes including those encoding antioxidant enzymes in transgenic Arabidopsis plants.

P 4.52 - late abstract- Effect of watering suspension on the physiological behavior of some barley ecotypes

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In Tunisia, the post-anthesis water deficit for cereals takes place almost every year. The identification of tolerant barley varieties or ecotypes to this stress is of great importance for crop improvement. To fulfill this objective, we evaluated the response of 6 barley ecotypes subjected to one week and three week periods of water deficit. Our results showed that Souihli, Sidi Bouzid and Tozeur 1 ecotypes have maintained higher foliar water potential allowing them an hydrated tissues cells under moderate and severe stress. On the other hand the other ecotypes showed lower water potentials. After one week of stress, we observed for this ecotypes a significant accumulation of proline and a high peroxidase activity, thus allowed them to withstand the effect of oxidative stress. Therefore, the membrane integrity, especially those of the thylakoids was preserved without a major affecting the chlorophyll content. After the severe stress (21 days of holding water), the peroxidase activity decreased for Sidi Bouzid and Souihli's ecotype and remained moderate for Tozeur 1. This must be due to an acclimatization of these plants to water stress. However, for the ecotypes originating from the North, we recorded a high reduction of the foliar water potential and chlorophyll content witch is associated with lower accumulation of praline content and a significant peroxidases activity showing their lack of tolerance to water stress.
P 4.53 - late abstract- Phospholipase D alpha is involved in drought stress signaling in Arabidopsis

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Different members of the phospholipase D (PLD) gene family are responsive to osmotic stress, cold, drought, wounding, pathogens or treatment with abscisic acid (ABA) and ethylene. Details of the signaling pathways through which any of the PLD gene products act are not yet understood in plants. PLD alpha-derived phosphatidic acid interacts with ABI1 phosphatase 2C and promotes abscisic acid signaling. Plants with abrogated PLD alpha show insensitivity to ABA and impaired stomatal conductance. We withheld water from 7 weeks old Arabidopsis thaliana (Col-0) and antisense- PLD alpha (anti-PLDa:Col-0) plants in a controlled environment chamber for 10 days. Diurnal leaf water potential (LWP) measurements showed that anti-PLD alpha had lower LWP than Col-0 both in control and drought stress conditions. Photosynthesis was more affected in drought stressed anti-PLD alpha than in Col-0. qRT-PCR revealed up to 18-fold lower values for PLD alpha transcripts in anti-PLD alpha plants than in Col-0. Microarray expression profiles showed differential expression of 1199 genes out of 20700 genes. PLD delta, which decreases H2O2-induced cell death, was upregulated in anti-PLD alpha and down-regulated in Col-0 suggesting a compensatory role for PLD delta in the antisense genotype. Six GTP-binding protein genes were down-regulated in Col-0 but were either up-regulated or unchanged in anti-PLD alpha. qRT-PCR results confirmed differential expression of ROP8, a Rho-like GTPase homolog. In mammals, small GTP binding proteins regulate downstream PLD activity. Increased expression of ROP8 in anti-PLD alpha suggests a similar mechanism in plants. ROP8 mutants will be analyzed to dissect its role in drought signaling.

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P 4.54 - late abstract- Effect of nitrogenous fertilizing on nitrate reductase activity in leaves of spring barley under drought stress conditions

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Effect of nitrogen rates on NRA (nitrate reductase activity) in leaves of spring barley (Kompakt variety) was investigated in pot experiment at normal atmospheric conditions. Individual pots were fulfilled with soil (Haplic Luvisols, 16 kg per pot): pH = 5.9; N= 11.3 mg.kg⁻¹; P = 44 mg.kg⁻¹; K = 224 mg.kg⁻¹; Ca = 2026 mg.kg⁻¹; Mg = 448 mg.kg⁻¹. There were applied the following rates of N per pot: 0.0 g (treatment 1), 1g (treatment 2) and 2g (treatment 3) in the form of liquid N-fertilizer DAM - 390. Each treatment was 4 times repeated. The plants were grown under optimum water moisture regime (60% of full water retention capacity - FWRC) and drought stress was applied during the growth stage of tillering, shooting and earing, respectively. On the course of the stress period the water content in soil was maintained on the average level of 15-20% of FWRC). After finishing respective stress period the plants were further grown under optimal water regime. Samples of material were taken after stress finishing in respective growth stages and NRA was determined by Jaworski (1971) method in Barker (1974) modification. Achieved results show that NRA was in all fertilized and unfertilized treatments significantly higher under optimal water regime than in respective treatments which were exposed to drought stress. When the plants were subjected to drought stress during tillering the highest value of NRA (18.9 mg N-NO₂⁻·g⁻¹ of fresh plant matter) was found out at the treatment 2. In treatment 2 it was 16.7 mg N-NO₂⁻·g⁻¹ and in control treatment 1.7 mg N-NO₂⁻·g⁻¹. The differences of NRA in fertilized and unfertilized variants were not statistically significant. After stress application in shooting growth stage the highest activity of enzyme (16.4 mg.g⁻¹) was determined at treatment 3 comparing to 5.6 mg.g⁻¹ under the treatment 2. The difference was statistically significant. Similarly the plants stressed during earing showed higher NRA (65.5 mg.g⁻¹) at treatment 3 than in treatment 2 (11.6 mg.g⁻¹).
P 4.55-late abstract- The evaluation of yield stability and antioxidant enzymes activity level with affected by selenium element under drought stress condition in oil sunflower varieties

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This study was carried out in order to determine the selenium effect on antioxidant enzymes activity at drought stress condition in 2003. During growth season some traits such as seed yield, harvest index, the activity of antioxidant enzymes such as SOD, GPX, DHG, MDA, CAT were measured. The results showed that selenium has significant effect at 99% level on antioxidant enzymes activity in no irrigated treatments. Comparison of irrigated treatments showed that increasing the activity of these enzymes under drought stress condition due of its inhibitory role on active oxygen.
**P 5.01 - Genetic Transmission of drought related morpho-physiological characters in wheat (Triticum aestivum L.)**

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Recent studies on a number of drought related morpho-physiological characters of wheat have been directed toward estimation of heritability and genetic advance. Six wheat varieties/ lines and six derived F2 hybrids were studied to ascertain and compare heritability and genetic advance for plant height, number of tillers per plant, spike length, days taken to maturity, no of grains per spike, number of stomata(upper flag leaf surface), epidermal cell size, 1000-grain weight, protein content and grain yield per plant. Most of these characters had high heritabilities and expected genetic advance. Prospects of genetic improvement for all the characters studied are evident. The most promising cross combinations are WL60x LU26S and WL61x LU26S. These traits therefore, deserve better attention in future breeding projects for evolving better wheat for stress environments.

**P 5.02 - Bahiagrass (Paspalum notatum Flugge) with engineered environmental stress regulon**

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Bahiagrass is an important turf and forage grass in the southern USA and in the subtropical regions around the world. The objective of this experiment was to further enhance the productivity and persistence of bahiagrass in salt affected regions by over-expression of the stress inducible transcription factor CBF3. Transcription factors like CBF3 are capable of activating the expression of multiple genes involved in protection against environmental stresses (Kasuga et al. 1999). The CBF3 gene and HVA1 promoter candidates were isolated from genomic wild or cultivated barley DNA by PCR. Primers for isolation of target genes were designed according to the published cultivated barley sequences. Plant transformation vectors were constructed on basis of vector pJFnptII (Altpeter et al. 2000). Biolistic gene transfer was carried out 6 weeks after initiation of callus cultures from mature seeds. Twenty-five independent transgenic plants expressing the selectable nptII gene were regenerated on paromomycin containing medium and confirmed with NPT II-ELISA (Agdia) (Altpeter and James 2005). Transgenic plants over-expressing CBF3 are currently identified by real time RT-PCR and will be subjected to salt stress in a completely randomized block design in a hydroponics system. Survival after salt stress will be visually scored and biomass production will be evaluated four weeks after recovery from salt stress. Data correlating CBF3 over-expression in transgenic bahiagrass with salt stress response will be presented.


P 5.03 - In vitro evaluation of citrus rootstocks tolerance to salt and boron.

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Citrus are fruit tree species that can grow in semi-arid zones under controlled irrigation conditions. However, these species present low tolerance to saline soils. To increase the cultivated area in semi-arid zones of Chile, it is basic to rely on citrus rootstocks tolerant to high concentrations of chloride and boron. Tolerance to NaCl and BO3- and its combinations, was evaluated in vitro in three citrus rootstocks. Plant growth (stems and roots) was registered and also the increase in fresh and dry weight. Foliar analysis showed correlation between toxicity symptoms and accumulation of ions. All rootstocks showed high sensitivity to chloride, being C-35 citrange the most tolerant. Boron in high concentrations did not cause severe damage. The simultaneous exposure to both ions resulted similar to NaCl indicating that chloride is determinant in causing symptoms.

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P 5.04 - Drought-induced changes in chemical composition of some Mediterranean shrubs

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We determined if drought induce nitrogen retranslocation in some Mediterranean shrub leaves, as suggested from studies of annual changes in plant nitrogen content. To test this, crude protein (CP) content and cell wall components in terms of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were assessed in five Spanish shrub leaves (Quercus pyrenaica, Cytisus scoparius, Genista floridch, Genista scorpius and Rosa canina) harvested during wet (Spring) and dry (Summer) season of 1996 and 1998. Shoot N concentration decreased in all species during drought occurred either in 1996 (15-42 %) or in 1998 (21-53 %). The lowest and the highest values were recorded in G. floridch and Q. pyrenaica, respectively. Cell wall components followed an opposite trend. Leaves from C. scoparius revealed the largest increase of NDF (64 %) and ADF (47 %) in 1996 and ADL (216%) in 1998. No consistent pattern with respect to drought tolerance was apparent in these chemical composition changes among shrubs. G. floridch and G. scorpius (leguminous) seem to be more tolerant and the magnitude of either CP decrease or cell wall content increase was lower as compared to the remaining species. It was suggested that decreases in leaf nitrogen (N) status during drought is a consequence of retranslocation likely result in lower photosynthetic capacity and decreased whole—plant carbon gain following relief of water stress after rain. Drought-induced retranslocation may serve to protect plant N from loss of herbivory during periods when soil N uptake and carbon assimilation are limited by water availability.
P 5.05 - Genetic transformation for salinity and drought tolerance in plants

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Environmental stresses are major factors that drastically affect the crop productivity. Genetic engineering can induce overexpression of genes of interest to get maximum function (Zhang and Blumwald 2001) and genes from sources other than plants like bacteria are being used to induce insect resistance, tolerance (Ahmad et al. 2002). In this study tobacco plants have been transformed with heat Shock family related transcription factor (HSR1) gene from Candida tropicalis and Arabidopsis gene AVP1 (Arabidopsis thaliana vacuolar pyrophosphatase H+ pump) with CaMV 35s tandem promoter to increase drought/salt tolerance. A genomic library of Candida tropicalis in a yeast multicopy plasmid has been screened for clones conferring salt tolerance upon transformation into S. cerevisiae. The best halotolerance clone contained an open reading frame encoding a predicted protein of 728 amino acids with homology to transcription factors of the heat-shock family. This novel gene was named HSR1 and is present in single copy in the C. tropicalis genome. Upon transformation into S. cerevisiae it increases the expression of ENA1, a major determinant of salt tolerance encoding a cation-extrusion pump (Rashid et al. 2000). The ORF of HSR1 was inserted in a plant transformation binary vector pBIN+ with upstream regulatory sequence and was introgressed in Nicotiana tabacum by Agrobacterium-mediated plant transformation method. The AVP1 ORF with a tandem repeat of 35S promoter was cloned in pPZP212 vector and Agrobacterium-mediated transformation was done. Homozygous lines have been produced by raising seeds up to three successive generations and used for analysis. In salt screening both transgenic plants were growing well up to 250-300 mM NaCl whereas the control plants died and could not recover after ten days of 200 mM NaCl treatment. Other analyses including ultrastructure studies, immunolabeling, Na/K, RWC etc. showed that transgenic plants are responding differentially and are tolerant to these stresses.

P 5.06 - Role of quercitol in drought stress adaptation of eucalypts

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The occurrence of the cyclic polyol quercitol among certain eucalypt species correlates strongly with the distribution of these eucalypts in arid environments. Yet, the function of quercitol in stress adaptation to low internal and external water potentials is unknown. We investigated the role of quercitol as a stress metabolite in a glasshouse experiment containing 13 eucalyptus species. In a field study using Eucalyptus astringens we investigated changes in quercitol concentrations in different plant organs and other ecophysiological parameters at different times of a year in a mediterranean environment in Western Australia. Seedlings of all species investigated contained quercitol and it occurred in leaves, branches, stems and roots of these species. Quercitol concentration decreased during the growth of well-watered plants and drought stressed plants of “mesic” species, whereas it was maintained or increased in droughted “xeric” species in the glasshouse experiment. In “xeric” species in the glasshouse and in E. astringens in the field tissue concentrations of quercitol increased after drought exposure (up to 300 mmol kg DW) and contributed to an overall increase in leaf osmolality. Quercitol played a vital role in the osmotic adjustment and contributed to around 20% of the total osmotic potential of E. astringens in all plant organs.
P 5.07 - Antioxidant activity and PS II efficiency in rice under water deficit

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The effects of water deficit on PSII activity and some components of the antioxidant system were studied in rice under glasshouse conditions. Water deficit was imposed by withholding watering to 90-day-old plants and was followed over a period of 27 days when relative water content of the youngest fully expanded leaf decreased from 94 to 77%. Drought induced an over 30% increase in lipid peroxidation and was not associated with changes in hydrogen peroxide contents, which remained stable throughout the experiment. Drought stimulated the accumulation of ascorbate and glutathione pools by 60 and 40%, respectively. The latter was matched by a drought-induced increase in glutathione reductase activity. Quantum yield of PSII (ΦPSII) and the fraction of open reaction centres in the light (qP) of droughted plants was 50-60% lower than that of watered plants. The efficiency of open PS II reaction centres in the light was also affected by drought but to a much lesser extent than ΦPSII, indicating that over reduction of Q A was the main limitation of photosynthetic electron transport under drought. The coordinated changes in lipid peroxidation and PS II activity induced by drought suggests down-regulation of photosynthetic electron transport can be in part attributed to loss of integrity of the thylakoid membrane during drought. Increases in ascorbate and glutathione might have helped in keeping H₂O₂ at low levels during drought and suggest that other active oxygen species, probably produced in Fenton-type reactions, could be responsible for the increase in lipid peroxidation in droughted rice plants.

P 5.08 - Physiological parameters of drought tolerance in relation to yield and yield stability in faba beans

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Faba beans belong to the high yielding legumes and they are interesting elements of crop rotations – especially with in view of organic farming. The seeds have a valuable starch and protein composition and breeding has already done a lot to improve quality for food and feed - for instance by reducing the content of antinutritive substances. Nevertheless, cultivation of this crop shows a declining tendency in Central Europe and mainly in Germany. One reason for that is a lack in yield stability caused by poor drought tolerance. Investigations under stress and control conditions in field and pot trials have shown variability in yield stability of faba beans measured by various indices. On the other hand, a relatively high correlation has been found between yield under control conditions and that under stress conditions, the higher yielding genotypes being characterized by a lower yield stability. Physiologically, this could be put down to the low variability between faba bean genotypes regarding their adaptation of water use efficiency to drought stress conditions due to a low potential for osmoregulation. A range of physiological parameters as accumulation of free proline and soluble sugars, membrane stability and changes in chlorophyll fluorescence have been investigated under controlled stress conditions. Results are related to stress yield and yield stability, respectively, and the suitability of these parameters as indirect selection criteria is discussed.
P 5.09 - Comparative Map and Trait Viewer (CMTV): an efficient tool to display and identify genomic regions from large and diverse data sets

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A wealth of genomic data has been produced over the past few decades, by functional and molecular marker approaches for a variety of species and from genomics and quantitative trait loci (QTL) analysis. Researchers need efficient and intuitive means to integrate this information in order to identify common genomic regions and genes controlling the variation of target phenotypic traits across diverse conditions. To help achieve this, a Comparative Map and Trait Viewer (CMTV) tool was developed in order to construct dynamic aggregations of a variety of types of genomic data sets. By algorithmically determining correspondences between sets of objects on multiple genomic maps, the CMTV can display syntenic regions across taxa, combine maps from separate experiments into a consensus map, or project data from different maps into a common framework using dynamic coordinate translations between source (e.g. the latest IBM map for maize) and reference maps. Once a region of interest has been identified as a result of the accumulation of significant QTL of interest across traits, environments and crosses, CMTV can search and display additional QTLs meeting a particular threshold for that region from genomic databases of various species, or other genomic data such as sets of differentially expressed genes located in this region. Further developments of the CMTV include the display of QTL by environment interaction as well as statistical tools based on QTL meta-analysis, to refine the region of consensus QTL locations identified in a study. Here, we shall focus on the utility of the CMTV in the interpretation of results generated by common QTL analysis software tools, and in the combination of diverse genomic data sets across genomes and experiments.

P 5.10 - Gas exchange and water relations as influenced by water deficit in an under-utilised and neglected crop: grass pea (Lathyrus sativus L.)

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Grass pea (Lathyrus sativus L.) is an important crop in drought-stricken areas. Although it is accepted that this species is well adapted to arid conditions, the physiological bases of its resistance mechanisms to water deficit remain unknown to date. To better understand how this under-utilised crop cope with drought, whole-plant responses to controlled drought-stress were studied in three grass pea accessions with winged stem margins: Raipur, Bangladesh and Adet originating from India, Bangladesh and Ethiopia, respectively. In fully hydrated plants (Ψᵢ = -0.4 MPa leaf water potential), leaf stomatal conductance (gₛ) was slightly higher in Bangladesh and Adet than in Raipur, although the latter fixed substantially more CO₂ than the other two cultivars. Surprisingly, gₛ in the stems was significant in all three cultivars. Furthermore, measurements of net photosynthesis and O₂ evolution revealed a feature unique to Raipur: stems with photosynthetic capacities close to that measured in the leaf tissues. In response to decreasing Ψᵢ (-0.4 MPa < Ψᵢ < -2.0 MPa), typical relationships between net photosynthesis and gₛ were obtained. Maximum photosynthetic rates decreased abruptly when Ψᵢ reached -1.8 MPa, in the three cultivars. However, water use efficiency was significantly higher in Raipur than in the other cultivars. Therefore, after 21 days of water withholding, 100% was obtained amongst Raipur plants whereas survival rates were much lower in Bangladesh and Adet. Together, these results suggest that amongst the three Lathyrus cultivars considered herein, Raipur is the most resistant to water deficit, possibly because of its assimilating stem margins.
P 5.11 - Adaptation of Medicago sativa cv. Gabès to water stress induced by high salinity

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A long term (4-week) high NaCl stress (150 mM) induces, in alfalfa source leaves, a strong reduction of area and a decrease of relative water content. However, tissues hydration is partly maintained through the decrease of $\Psi_m$, realized by the increase of soluble sugars content and proline accumulation. These salt-induced modifications of water status varied with leaf position and were significantly higher in the lower than in the upper leaves. Moreover, cellular damages as DNA fragmentation and plastid alteration were observed but were more pronounced in lower leaves. These observations may be the result of a secondary oxidative stress associated to water stress as shown by the increase of lipid peroxides content in particular in lower leaves. Water status seems to activate defence mechanisms and activities of detoxifying enzymes were stimulated but responses varied with leaf age. Activity of Cu/ Zn-SOD was increased, but only in the lower leaves; catalase and ascorbate peroxidase activities were stimulated in the upper ones, whereas it decreased in the lower leaves. The adaptation of the perennial Medicago sativa cv Gabès to high salinity is related to maintenance of an adequate water status realized by osmotic adjustment and to an efficient detoxification of toxic $O_2$ species in upper source leaves allowing them to supply sink organs with assimilates.

P 5.12 - Adaptation of photosynthetic responses of plants to drought and high temperature

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In general, photosynthesis is a process with a considerably high level of resistance to the extremal environment. Undoubtedly, the component photosynthetic processes are a good indicator of specific and non-specific effects of unfavourable environmental factors (e.g. drought, high temperature). Regardless of its importance, photosynthesis is only rarely included into plant breeding. Cereal breeding for drought tolerance is mainly based on empirical yield response rather than temporal and spatial dynamics analyses of physiological responses. Moreover, a deep understanding of the molecular mechanisms of any process regulation often does not reflect whole-plant responses during ontogenesis. In our work the growth, metabolic and photosynthetic reactions of barley and wheat genotypes of different ecological zones were quantified under drought (up to 50% of RWC) and high temperature (from 25 to 45 °C) and a spectrum of gasometrical, porometrical, psychometrical, colorimetric and fluorescence methods were used in the analyses. When drought and high temperature were applied concurrently, additive and interactive effects were found. Both stomatal and non-stomatal effects of drought, as well as impact of leaf $\Psi_w$ decline and temperature increase on photosynthesis regulation were evaluated. Our results show the regulation changes of photosynthesis and energy fluxes as visualised by integration of the JIP test and Biolyzer program (Strasser 2001) and leaf fluorescence imaging measurements. Genotypes with a higher osmotic adjustment capacity better overcome different climate extremes. High temperature seems to be a critical factor affecting directly the photosynthetic apparatus, therefore studying the plant thermotolerance and photosynthetic adaptations will be useful for future genotypes.
P 5.13 - Comparison of four methods for measuring leaf osmotic potential

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Osmotic potential (p) of leaves is a key component of plant water relations. The aim of this study was to determine the best rapid alternative to pressure-volume analysis for measurement of p. We compared osmometry of pressurized expressed sap, freeze-thaw leaf discs and hot water extracts with pressure-volume analysis using leaves of three sclerophyllous and two non-sclerophyllous tree species. The expressed sap method produced values of p consistent with pressure-volume analysis and dilution by apoplastic water. However, the apoplastic water fraction obtained from pressure-volume analysis provided a poor correction for apoplastic dilution. Freeze-thaw leaf discs and hot water extracts produced more negative values of p than did expressed sap, though all methods appeared sensitive to changes in p and were consistent between the species tested. We conclude that osmometry of expressed sap is the best technique for rapid assessment of p. Osmometry of expressed sap was sensitive to changes in p and was consistent across species, it produced values consistent with pressure-volume analysis and apoplastic dilution, and it was the most rapid method tested.

P 5.14 - How does water stress affect C4 photosynthesis at different CO₂ levels?

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C4 plants have a specialized photosynthesis that leads to greater water use efficiency and ecological success in arid environments. With the increase of atmospheric CO₂ and the consequent global warming of the planet, the decrease of water consumption is now a priority and C4 plants can become more important since they are better adapted to higher temperatures and drought conditions. The effect of water deficit in CO₂ response curves was studied in plants of the C4 grass *Cynodon dactylon* var. Shangri-Lá grown hydroponically. A reduction of the nutrient solution water potential from -0.5 to -1.6 MPa was obtained with polyethylene glycol 4000 and the leaf relative water content (RWC) was used as an indicator of the water stress level. Gas-exchange and Fluorescence parameters at high irradiance and different CO₂ levels (50 to 1400 μmol mol⁻¹) were measured simultaneously. The photosynthetic rate, the stomatal conductance and the quantum yield of PSII decreased with the RWC. However, the response of these parameters to the CO₂ concentration was not the same for each stress level. Both the shape of the curves and the maximum values obtained were different in each case. In control and moderately stressed plants there was an increase of the photosynthetic rate with the CO₂ concentration followed by a slight decrease at the highest CO₂ levels. The stomatal conductance was markedly affected by the increase of the CO₂ concentration, but can this be related with the limitation of photosynthesis at high CO₂ levels?
P 5.15 - A stay-green wheat that produces high yield under rain-fed conditions in sub-tropical Australia

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Cereals with the ‘stay-green’ trait maintain green leaves for longer during post-anthesis drought. The stay-green trait has been identified in the CIMMYT wheat line SeriM82. In trials under both water-limited and non-limiting conditions in sub-tropical Australia, SeriM82 has yielded 12% higher than the widely grown local variety Hartog. In detailed physiological studies, a SPAD meter was used to measure leaf greenness, a surrogate for chlorophyll content. In the winter seasons of 2003 and 2004, the leaves of both varieties had similar chlorophyll content prior to anthesis, but Hartog plants lost chlorophyll more rapidly through the grain filling period and matured earlier than SeriM82. Photosynthetic rates were similar at anthesis and grain development proceeded at a similar rate for both varieties. SeriM82 accumulated more mass in individual stems up until anthesis and was able to translocate more carbon to each spike. SeriM82 also accumulated more nitrogen during grain filling. Under conditions of severe terminal drought, SeriM82 roots extracted soil moisture to the maximum depth of measurement (1.5 m) at least as rapidly as Hartog, reaching the lower limit of extraction by about anthesis. This suggests that extraction from deeper in the profile was required to sustain the plants during grain filling. Further experiments are underway to determine whether SeriM82 can access more water at depth or extract more water from a given soil volume than Hartog. The ability to retain green leaves for longer increased SeriM82’s grain filling period, allowing it to accumulate more carbon and nitrogen in the grain.

P 5.16 - Responses to sub-optimal temperatures in two different clones of Eucalyptus globulus Labill

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In Mediterranean-type climates water is available in the cool winter, whereas hot and dry conditions prevail in the summer. Therefore a successful evergreen tree must be capable to acquire carbon and grow under lower rather than higher temperatures. Moreover, several studies showed that drought resistance and cold resistance mechanisms are sometimes correlated. For these reasons we hypothesised that, under the Mediterranean-type climate, successful plant genotypes in dry environments may have higher growth rates at sub-optimal temperatures than drought-sensitive plants. If this is true it will allow a clone less susceptible to drought to prolong carbon assimilation and active growth throughout the water-stress-free period. Therefore, differences in the response to sub-optimal temperatures either in growth or in plant hydraulic properties can play a fundamental role in the differences in drought stress resistance between Eucalyptus clones. The aim of this work is to evaluate the effect of sub-optimal temperatures in growth and plant hydraulic properties of two contrasting clones of Eucalyptus globulus Labill. The two clones under study differed in theirs sensitivities to water deficits (CN5-drought tolerant and ST51-drought sensitive). Under water deficits, CN5 maintained a higher carbon allocation to the root system with lower values in the leaf-to-root-area ratio. Sub-optimal temperatures (10/ 5 ºC, day/ night, respectively) led to a general decrease in growth and significant reductions in leaf area ratio, specific leaf area, root hydraulic conductance, rate of photosynthesis and stomatal conductance in comparison to plant responses at indoor temperature.
Water stress is the most important limitation to plant productivity. The development of drought resistant cultivars has become extremely important as we face the dramatic climate changes over the last years. Maize is one of the world’s most cultivated crops, but its production is limited to warm regions, where water limitation is often common. In six Portuguese maize cultivars (AD3R, PB64, PB260, PB269, PB304, PB369), from different regions of Portugal, drought was imposed, over one week, withholding water supply. Supply of water was restored afterwards and the plants studied for another week. Gas exchange and chlorophyll fluorescence measurements were made. Relative water content (RWC) was assessed as a measure of plant water status. In control plants, RWC was superior to 90% in all cultivars but stressed plants showed a strong decrease, especially in PB260. Photosynthesis reached values close to zero after a week of stress and all cultivars recovered, with the exception of PB369. The same pattern was observed in transpiration and stomatal conductance. AD3R showed the highest water use efficiency (WUE) and PB64 the lowest. The maximum potential photochemical efficiency of photosystem II and the photochemical quenching showed a small decrease in the last day of stress in all cultivars. The non-photochemical quenching remained constant. The electron transport rate decreased but recovered in all cultivars. PB269 seems to be the cultivar most tolerant to drought, showing the highest rates of photosynthesis and an intermediate WUE. On the contrary, PB369 seems to be the most susceptible cultivar to water stress.

Drought is a major constraint for common bean (Phaseolus vulgaris) yield. A product of the common bean improvement program at INIFAP is the drought tolerant ‘Pinto Villa’ cultivar. This variety has shown a higher productivity and higher crop index when compared to drought susceptible cultivars such as ‘Canario 60’, when grown in semi-arid regions in Mexico. In response to terminal drought ‘Pinto Villa’ induces the acceleration of its life cycle, concomitant with the loss of mature leaves. These results led us to propose that drought resistance in this variety is related to an increased assimilates-mobilization from leaves (source tissues) to pods (sink tissues) in response to terminal drought. In greenhouse experiments, ‘Pinto Villa’ (drought tolerant) and ‘Canario 60’ (drought sensitive) plants, were grown under both optimal irrigation and water deficit conditions. At flowering time, plants were incubated in the presence of \(^{14}\text{CO}_2\) for 4 hours. Subsequently, radioactive starch was quantified both in source and sink tissues at three different time points prior to pods maturation. The results from these experiments indicate that water limitation treatment induces faster starch accumulation in the drought tolerant variety pods than in the pods of the drought sensitive cultivar. Consistently, the drought tolerant cultivar induces a reduction in leaves starch in contrast to that found in the susceptible one. The data in this work supports the hypothesis described above, and indicate that the modulation of carbon mobilization has been a successful adaptive strategy in response to drought exposure in common bean.
P 5.19 - Adaptative mechanisms of olive tree to drought

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Olive trees is able to resist drought stress by a broad range of physiological and biochemical mechanisms. Olive trees lower the water content and water potentials of their tissues, establishing a high potential gradient between leaves and roots. In drought conditions, olive plants stop shoot growth but not photosynthetic activity and transpiration. This allows continued the production of assimilates as well as their accumulation in the various plant parts, in particular in the root system, creating a higher root/leaf ratio compared to well-watered plants. Active and passive osmotic adjustment play an important role in maintaining cell turgor and leaf activities which depend on it. Sugars, especially mannitol and glucose, play a major part in the osmotic adjustment of leaves. In addition, the osmotic adjustment observed in the root system allows maintenance of cell turgor, avoiding or delaying the separation of roots from soil particles. Moreover, in trees subjected to severe drought the non-stomatal component of photosynthesis is affected and likely a light-dependent inactivation of the photosystem II occurs. The increase of malondialdehyde content and lipoxygenase activity, two markers of oxidative damage related to drought stress, suggest that water deficit is associated with lipid peroxidation mechanisms at cellular level both in leaves and roots. Finally, in olive trees, the activities of some antioxidant enzymes, such as superoxide dismutase, catalase, ascorbate peroxidase and peroxidase, involved in the scavenging of activated oxygen species and in other biochemical pathways, increase during a period of drought. This suggest that higher activities of some antioxidant enzymes are required for a better protection against oxidative stress related to water deficit.

P 5.20 - Effect of water deficit during flowering on growth and morpho-physiological responses in sesame (Sesamum indicum L.)

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Sesame (Sesamum indicum L.) is an oil-seed and cash crop with high nutritional and added values. In semi-arid Senegal where drought often occurs during crop development, its cultivation is recent and its promotion is largely recommended by the government for fighting against the poverty considering the high interest for the rural populations. The purpose of this study is to characterize the agro-physiological responses and identify potential screening criteria for selection for drought tolerance. Soil moisture (θs), leaf area index (LAI), mid-day leaf water potential (Ψmd), the difference between canopy and air temperature (Tc-Ta), net photosynthesis (Pn) and maximal yield of photochemistry (ratio of Fv, variable fluorescence to Fm: maximum fluorescence = ΦP0) were measured during flowering-capsule production stage. Water consumption, considering RET cycle (real evapotranspiration during the whole cycle), of 249 and 184 mm were recorded for well watered and stressed treatments, respectively. After the with-holding of the irrigation, the decrease in Ψmd, Tc-Ta was noted earlier (18 Das) than in LAI (24 Das), Pn and ΦP0 (28 Das). Low grain yield and number of capsule per plant were also induced by water deficit. Hence, Ψmd, Tc-Ta and chlorophyll a fluorescence considering ΦP0 can be used as destructive (Ψmd) and non-destructive (Tc-Ta, ΦP0) tools respectively in screening for drought resistance in sesame.
P 5.21 - Agrophysiological traits of pre-harvest aflatoxin contamination in groundnut

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Groundnut contamination with aflatoxin constitutes a great threat to human and animal health in West Africa, with subsequent negative effects on agricultural production and commercialization. An efficient management of the risk due to aflatoxin contamination in semi-arid zones could be achieved through a better understanding of the interactions between the plant, the soil water status and Aspergillus flavus. For this purpose, two field experiments were conducted in 2002 and 2003 in a split plot experimental design at Bambey, Senegal. Three varieties (55-437, 73-30 and Fleur 11) were submitted to two watering regimes: well watered (WW), and water stressed (STR) during the grain filling phase i.e beyond 60 days after sowing. The results showed that a high fraction of transpirable soil water (FTSW > 0.8) or notably a low FTSW (<0.4) during this phase increased the risk of aflatoxin contamination. For all water regimes, only 55-437 exhibited a low aflatoxin contamination rate compared to Fleur 11 and 73-30. While under conditions of water excess (FTSW>1), 73-30 was more contaminated than Fleur 11. The ability of 55-437 to minimize aflatoxin contamination could be related to its drought responses. In fact, the lower leaf area index (LAI) of 55-437 compared to Fleur 11 resulted in limited water losses under water deficit condition, resulting in better leaf water status and consecutively in higher photosynthetic activity. This drought response of variety 55-437 combined with lower grain size trait allowed a better grain filling and maturation, warranty for a low aflatoxin contamination risk.

P 5.22 - Genetic analysis of some pepper (Capsicum annuum L.) varieties using three PCR-based markers

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RAPD-PCR, RFLP of the 18s r-RNA gene and chloroplast DNA polymorphisms were employed to estimate the genetic similarity among five different genotypes of pepper (Capsicum annuum L.). RAPD analysis was performed using ten random primers. The genetic similarity was estimated as band sharing (BS) for each primer between the genotypes (B1, B2, AC, K9 and F1). The results showed the highest genetic similarity of 90.0% between genotypes B2 and AC. These high numeric similarities suggest a common lineage or a very little genetic variation exists between these two genotypes. The lowest genetic similarity of 76.0% was detected between genotypes B1 and F1. Two pairs of primers were used to amplify 18s r-RNA gene and chloroplast DNA. The restriction of the 18s r-RNA gene using BamH I, EcoR I, Hind III & Hinf I and the pattern of chloroplast DNA revealed no polymorphisms. These data demonstrate the usefulness of molecular analysis in the detection of genetic relationships and evaluate the relative effectiveness of the different types of PCR-based markers in revealing variation among Egyptian and foreigner pepper genotypes.
P 5.23 - Characterizing root responses to low phosphorus in Pearl millet (Pennisetum glaucum (L.) R. Br.)

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In the Sahelian zone, low soil P could be as limiting as drought in pearl millet (Pennisetum glaucum (L.) R. Br.) productivity. The adaptation to low soil P was related to root alterations, particularly important for the acquisition of phosphorus. For this purpose, two experiments were conducted in the greenhouse, one in hydroponics and other in pots. In hydroponics, plants of Souna 3 variety were grown for 30 days with three levels of P (P0 = 0.0, P1 = 11 and P = 232 mgP l⁻¹). In the pot experiment, two varieties (Souna 3 and IBMV8402) were subjected to two watering regimes: well watered (WW), and water stressed (STR) at the vegetative phase. Phosphorus treatment consisted of application of phosphate fertilizer (P₂O₅) at the rate of 23 kg ha⁻¹ (F1), or without phosphate application (F0). Results showed that pearl millet presented an alteration of root parameters under phosphorus deficiency especially on root volume (RV). Different genotypic responses to water and phosphorus availability were observed in terms of rooting parameters and shoot growth. On the basis of leaf water potential, Souna 3 appears more drought tolerant than IBMV8402. However, phosphorus supply should improve the drought response of IBMV8402. In addition, this later showed a better behaviour in non water-limited condition as well as in high or low P condition. Besides the condition of water stress and without P supply, IBMV8402 exhibited a higher P utilization efficiency in terms of shoot biomass production. These results suggested that genetic variability should be used to improve the adaptation of pearl millet in low soil P.
Co-adjustment of water losses and photosynthesis in leaves: a role for aquaporins?

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Under water stress, leaves close stomata to minimise water losses through transpiration and adjust their water balance. Because CO₂ enters the leaves through stomata, stomatal adjustments of water balance lead the plants to pay a prize in terms of decreasing CO₂ availability for photosynthesis. However, studies of our group and others in grapevines and other C₃ plants show that, under progressive water stress, not only stomata close thus limiting CO₂ entering the leaf, but there is also a tight co-regulation between stomatal closure and the mesophyll capacity of fixing CO₂. It has been demonstrated that decreased mesophyll conductance to CO₂ (gₛₑₘ) is the key point of the non-stomatal down-regulation of photosynthetic capacity under stress. Aquaporins play a major role in the regulation of water transport inside plant tissues, including the mesophyll, and their role may be especially important under water stress. Moreover, it has been recently demonstrated that expression of Nicotiana tabacum L. aquaporin NtAQ1P1 in Xenopus oocytes also results in increased membrane permeability to CO₂⁶. Therefore, it was tempting to hypothesise that aquaporins could be involved in gₛₑₘ regulation, providing a common link for water and CO₂ transport inside leaves, similar to stomata in the leaf-atmosphere interface. Due to the lack of transgenic grapevine plants differing in the expression of one or more aquaporins, the hypothesis was tested in tobacco plants with either deficient or over-expressed NtAQ1P1. Wild-type plants (WT), anti-sense plants deficient in NtAQ1P1 (AS), and NtAQ1P1 over-expressing plants (OE) were grown in saturating light, optimum irrigation and nutrition, 25 ºC and 50% relative humidity. Photosynthesis and chlorophyll fluorescence were determined at different light intensities and CO₂ concentrations. At saturating light, photosynthetic rates were 10% lower in AS plants and 20% higher in OE compared to WT. CO₂-response curves of photosynthesis also showed significant differences among genotypes. However, these differences could not be attributed to different Rubisco activity or RuBP content, as determined in vitro. Leaf mesophyll conductance to CO₂ was estimated to be 30% lower in AS and 20% higher in OE compared to WT plants. These results were confirmed by ¹³C discrimination analysis. Therefore, the present results demonstrate that aquaporin expression is involved not only in water transport but also in CO₂ transport through the leaves and photosynthesis. However, further analyses suggest that gₛₑₘ regulation is as rapid as stomatal regulation, responding not only to water stress but also to changing light intensity and/or CO₂ concentration in seconds to minutes, i.e. much more rapidly than aquaporin expression. We hypothesise that not only aquaporin expression, but also aquaporin gating may be involved in gₛₑₘ regulation.
**P 5.25 - A model to predict anthesis silking interval in maize: analysis of differential responses to water deficit of ear-axis organs**

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Delayed silking, resulting in an increased anthesis-to-silking interval (ASI), is commonly observed in maize subjected to environmental stresses around flowering. A shortened ASI is associated with maintenance of grain yield under drought stress. ASI is the result of differential elongation of ear-axis organs (husks, pedicel, rachis, ovaries and silks), but their responses to water deficits have never been quantified. In an attempt to build such a quantitative model, the responses of organs elongation to temperature and to a range of soil water deficits were studied on a temperate inbred line (F252). Plants were grown in pots and subjected to different environmental conditions (light, temperature, soil water content) in greenhouse and growth chamber. Soil water status was managed by weighing pots and adjusting water supply to the target soil water content. The growth rate of organs growth was measured from their initiation to the end of silk elongation. Specific non-destructive methods were developed to analyze silk growth at different positions along the ear. A detailed spatial analysis of silk growth was carried out to determine where and when elongation occurs. The growth rates of reproductive organs, and particularly silk growth rate, were negatively correlated to pre-anthesis soil water potential and largely explained the variability of ASI in the different treatments. These results will then be transferred and adapted to tropical inbred lines P1 and P2, used as parents of a segregating population, and to several contrasting RIL of this population.

**P 5.26 - Aegilops biuncialis as a potential gene source for improving drought tolerance of wheat**

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The physiological and morphological responses to water stress induced by PEG or withholding water were investigated in Aegilops biuncialis (Vis.) genotypes differing in the annual rainfall of their habitat (1050, 550 and 225 mm/year) and in Triticum aestivum (L.) wheat genotypes differing in drought tolerance. A decrease in the osmotic pressure of the nutrient solution from -0.027 MPa to -1.8 MPa resulted in high water loss, a low extent of stomatal closure and a decrease in the intercellular CO₂ concentration (Cᵢ) in the case of Aegilops genotypes, while in wheat genotypes osmotic stress induced increased stomatal closure, resulting in a low level of water loss and high Cᵢ. Nevertheless, under saturating light and normal atmospheric CO₂ level, the rate of CO₂ assimilation was higher for the Aegilops accessions even under strong osmotic stress than for the wheats. Moreover, wheat genotypes exhibited less or no O₂ sensitivity of CO₂ assimilation. These physiological responses were manifested in a decrease in the growth rate and biomass production, since Aegilops genotypes preserve a higher growth rate, especially in the roots, biomass production and yield formation after drought stress than wheats. On the basis of the results it seems that the strategy of Aegilops genotypes for avoiding drought stress is different from that of wheat plants, making them a valuable gene source for wheat improvement against drought stress.
Drought conditions strongly influence photosynthetic metabolism in a way that might be extremely important to determine a positive carbon balance in highly stressed environments, such as the Mediterranean area. However, plants may have evolved towards more efficient photosynthetic mechanisms, possibly including acclimation and adaptation of photosynthetic enzymatic traits. Because of its central role in photosynthesis, Rubisco is one of these potential traits to be selected under stressful conditions. Plants respond to low water availability by decreasing leaf diffusive conductances, which, however, leads to an increase of the barriers to diffusion of CO₂ to the primary site of carboxylation. We hypothesized that arid environments leading to water stress and, thus, decreased CO₂ availability for photosynthesis, may impose increased selection pressure on Rubisco for improving its specificity factor (τ), a measure of the relative affinity of the enzyme for CO₂ and O₂. To test this hypothesis, τ was measured on purified Rubiscos from 24 Mediterranean species having a variety of ecological, phylogenetic and morphological traits. A high variability in Rubisco was found among plants, which was related to environmental pressure factors and not to phylogeny. Rubisco τ was significantly higher in species inhabiting the most arid areas, and the Rubisco of a xeric species, Limonium gibertii, presented the highest τ value hitherto reported among higher plants. This was sequenced and some interesting residues were found to be different to other higher plant Rubiscos but identical to Galdieria. Finally, to check whether plants can also acclimate Rubisco kinetic properties to drought, τ was measured in tobacco leaves developed under different drought intensities. The results showed that Rubisco τ does not acclimate to water stress in the short time.

Plant and organ size exercises a major control over plant and crop water use. Under drought condition, small plants with small leaf area (LA) and leaf area index (LAI) use relatively less water and are expected to enter a state of plant water deficit later than large plants of greater LAI. Indeed, smaller plants generally offer a lower yield potential than larger plants. In order to study on morphological traits effective on drought tolerance in two contrasting cutleaf medic (Medicago laciniata (L.) Mill) genotypes, a factorial greenhouse experiment was conducted in a RCBBD. The drought stress levels consisted of -0.1, -0.5, -1.0 MPa as low, medium and high stress levels respectively and normal condition (FC = -0.03 MPa). Characteristics like the height of plant, number of internodes, internodes distance, and leaf area and shoot dry matter were determined. Results indicated that tolerant genotype had a significant superiority to sensitive genotype in the most of studied morphological characteristics. Interestingly this experiment showed that effect of drought stress reduced LAI in both sensitive and tolerant genotypes, but reduction of LAI in tolerant genotype was related to increase the dept of cut of the leaves rather than size, length, dehydration or desiccation of leaves. Moreover, height of plant in sensitive genotype was higher than tolerant genotype in normal condition, but tolerant genotype continued its growth and development under stressed condition which final height was higher than sensitive genotype. Reduction of LAI due to laciniate leaves may reduce transpiration areas with less effect on photosynthesis and plant development.
P 5.29 - Mechanism of osmotic adjustment in two different genotypes of cutleaf medics (Medicago laciniata (L.) Mill) under drought stress

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Osmotic adjustment is a biochemical mechanism that helps plants acclimatize to drought conditions. Many drought-tolerant plants can regulate their solute potentials to compensate transient or extended periods of water stress by making Osmotic Adjustment (OA), which results in a net increase in a number of solutes in the plant cells. In order to study the mechanism of osmotic adjustment and the role of osmolytes in sensitive and tolerant genotype to drought stress of cutleaf medic (Medicago laciniata (L.) Mill), a greenhouse experiment was conducted in 2004, at the Agricultural Biotechnology Research Institute of Iran, using a factorial arrangement in RCBD with three replications. Two genotypes of cutleaf medic, sensitive and tolerant to drought stress was treated in four levels of water stress include -0.1, -0.5, and -1 MPa as low, medium and high stress levels, respectively, and normal condition (FC = -0.03 MPa). Results indicated that tolerant genotypes had a significant superiority to sensitive genotype in most studied characteristics such as RWC, OA and organic solutes including proline, total sugar and inorganic solutes among K+, Ca2+ and Zn2+ during medium and high water stress levels. So this experiment showed that high RWC in drought-tolerant genotype was simultaneous with increase in OA and osmolytes in leaves and root of tolerant genotype. Since tolerant genotype was collected from arid areas (rainfall 170-190 mm y-1) this experiment indicate that OA is one of the major concern of tolerance, therefore it might be possible to use these characteristics for selection of tolerant medics or transfer them in alfalfa as a crop.

P 5.30 - Reproductive moisture stress compartmentation to study its differential impact on grain filling and fertility in IR50 and Moroberekan varieties

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Compartmentation of moisture stress during reproductive phase was carried out to know if the differential impact of moisture stress on grain filling and fertility in IR50 and Moroberekan existed. Moisture stress was induced: just prior to panicle initiation, at first flowering, at 50% flowering, 10 days after 50% and 20 days after 50% flowering, with a well irrigated as control to evaluate the impact of stress. The soil was maintained at field capacity by watering twice/ day. The contribution of roots in mitigating the stress during the moisture stress induction period was kept to a minimum by raising the genotypes in pots, as there was no provision of moisture reserves as in case of soil for roots characteristics to come in to effect. 50% flowering and 10 days after 50% flowering were found to be the critical stages for moisture stress both in IR50 and Moroberekan. The negative impact of moisture stress at 50% flowering and 10 days after 50% on single panicle weight, test weight and fertile spikelets per panicle was higher in IR50 than on Moroberekan. However, moisture stress at 50% flowering and 10 days after 50% flowering had no differential effect on number of sterile spikelets per panicle, total number of grains per panicle and spikelet density in the varieties. Moroberekan thus produced heavier panicles with greater fertile seeds and test weight despite stress prior to and before the critical stages.
Light-response curves give us a wealth of useful information about the photosynthetic mechanisms operating inside the leaves. Potted chrysanthemums (*Dendranthema indicum* cv. `Surf`) plants were subjected to two water stress treatments to determine alternation of their acclimation potential. The water stress treatments were as follows: 1-water supply at 40% of the level of the daily consumption of the control plants, and 2-overwatered plants. The net photosynthetic rate (Pn) of intact leaves of experimental pot plants grown in the greenhouse was measured by infrared gas analyser in photosynthetic photon flux density (PPFD) from 0 to 1200 μmol.m⁻².s⁻¹ and constant conditions (leaf temperature 25 °C, vapour pressure difference 15 mbar and at ambient CO₂ concentration 400 ppm). Under low light intensity (PPFD 50 μmol CO₂.m⁻².s⁻¹) photosynthesis rates of observed plants were similar. Increasing light intensity increased photosynthesis rate within all variants, but with different values. Average Pn value of control plants at 1200 PPFD was 18.52 μmol CO₂.m⁻².s⁻¹, whereas overwatered plants reached 16.08 μmol CO₂.m⁻².s⁻¹ and plants with water supply at the 40% level of the daily consumption of the control plants reached the lowest saturation photosynthetic rate 9.21 μmol CO₂.m⁻².s⁻¹. Photosynthetic inhibition under water and light stress conditions are determinants for plant growth and survival in generally.
P 5.33 - Periodicity in seedling drought tolerance of Schismus arabicus from the Negev and Kara-Kum Deserts

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What are the mechanisms that ensure that dry stored seeds can measure the time when to germinate year after year or when seedlings will survive drought? *S. arabicus* is one of the most common pasture annuals in the Negev and Judean Deserts of Israel as well as in the deserts of Central Asia, such as the Kara-Kum Desert of Turkmenistan. Periodicity of seedling survival after drought, of 7 to 42 days, depends on the month of germination of the caryopses (seeds) of *Schismus arabicus* collected in the Negev. The percentage of surviving seedlings that had germinated and gradually dehydrated in June 2001, 2002, 2003, 2004 and 2005, was very low. None survived of about 4,000 seedlings that had germinated in July of those years. In contrast 100% survived after periods of drought, of the seedlings that had germinated during the growing season (Jan to Feb.). In all the experiments, 70 to 100% of the seeds germinated. Seedlings that germinated in different months also differed in the speed of root and shoot elongation after rehydration. In months with higher percentages of survival, which is in the growing season, seedling development was also faster. Is there a connection between the ability of the seedling to develop faster in the growing season and their ability to survive periods of drought? *S. arabicus* has a unique set of adaptations and survival strategies, which enable its seeds to germinate and plants to produce seeds even in years with rainfall amounts far below the annual average of 100 mm.

P 5.34 - Evaluation of flag leaf senescence in durum wheat as selection criterion under drought conditions of Eastern Algeria

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Studies were conducted under drought conditions during three seasons to clarify the relationship between senescence and yield. In the first experiment, senescence was evaluated at different stages of the grain-filling period in eight durum wheat varieties using numerical image analysis (NIA). The varieties were grown under early, severe drought conditions on the high plains of Sétif in Algeria. After flowering, three different irrigation treatments were applied. Treatment effect was small, while a genotypic effect was noted for most of the senescence parameters. Senescence correlated to biomass, while the maximal rate of senescence, Vsmax, correlated to thousand-kernel weight. In the second part of these studies, ten durum wheat cultivars were grown during two seasons Mean leaf senescence was 73% higher in season 1, compared to season 2. The two old cultivars Mexicali and Yavaros showed strong decreases, while the other eight cultivars showed increases in leaf senescence in season 2, compared to season 1. In season 1 average senescence of the five top yielding genotypes (Kucuk, Altar, Sooty9/ Rascon57, Yavaros and Tilo1/ Lotus4) was less than 45%, while in season 2 the five top yielding cultivars (Yavaros, Waha, Tilo1/ Lotus4, Dukem12/ Rascon21 and Mexicali) had more than 65% leaf senescence. Senescence was significantly and negatively correlated with grain yield in season 1, but not in season 2. The potential of the method of numerical image analysis for monitoring flag leaf senescence, detecting genotypic variability and selecting genotypes with delayed senescence is discussed.
Physiological, biochemical and agronomical responses of cowpea (Vigna unguiculata (L.) Walp.) genotypes to water deficit in greenhouse and field conditions

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Five genotypes of cowpea, Gorom local, KVX61-1, Mouride, Bambey 21 and TN88-63 differing in their susceptibility to water stress were experienced in greenhouse and field to study their agrophysiological and biochemical responses to water deficit at flowering stage. Effect of this stress on leaf water potential (Ψf), gas exchanges, foliar proline and starch contents, vitality index (SFI), canopy temperature, yield and its components was assessed during the pot culture and/or the field trial. In pot culture, water deficit increased significantly the proline content (from 0.35 to 1.96 mg g⁻¹ DM in mean) of the five genotypes while gas exchanges and starch content decreased (respectively from 19 to 2.25 μmol CO₂ m⁻² s⁻¹ of net photosynthesis and from 61.28 to 17.47 mg g⁻¹ DM in mean). SFI decreased significantly for the five genotypes. Gorom local, Mouride, KVX61-1 and TN88-63 decreased significantly their Ψf (from -0.55 to -0.92 MPa in mean) while Bambey 21 maintained it (from -0.4 to -0.43 MPa). In field conditions, drought stopped gas exchanges of Gorom local, KVX61-1, Mouride and Bambey 21. KVX61-1 and Bambey 21 showed the highest decrease of SFI. The yield and its components were more affected for Bambey 21 (> 60%) which accumulated the lowest proline quantity (0.44 mg g⁻¹ DM). Our results revealed that adaptative responses of genotypes to water deficit in greenhouse can be different from that in field. Furthermore, the effect of water deficit on the physiological and biochemical parameters could explain the agronomical responses notably in the field.

Germination of Salicornia Bigelovii under different sea water and temperatures stresses

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The effects of different seawater concentrations (0, 25, 50, 75 and 100%) and temperatures (20, 25 and 30 °C) were examined on the germination of Salicornia Bigelovii seeds. There was a decrease in germination percentage as the concentration of seawater increases. However, incubation under different temperature treatments showed different responses. 20 °C showed reasonably high germination per cent 99.25, 90, 88.3, 77.1 and 67.14% for the different seawater concentrations. Result of this study demonstrate the ability of this plant species to survive under arid and semiarid conditions.
P 5.37 - Mapping QTLs for plant growth in rice under water stress induced by polyethylene glycol

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The objective of this study was to dissect the genetic control of drought resistance related to shoot traits without the effect of root escape mechanism by a deep root system. Mild water stress (-0.3MPa) was induced by polyethylene glycol (PEG) 6000 to the ‘Akihikari’ (a lowland japonica rice cultivar) x ‘IRAT109’ (an upland japonica rice cultivar) backcross inbred lines cultured hydroponically in a greenhouse. Growth was evaluated in relation to transpiration characteristics. Polyethylene glycol treatment reduced relative growth rate (RGR; biomass production/total biomass) by 6-69% or an average of 31%. One QTL for RGR was commonly detected in the PEG-treated and the control plots, while another QTL for RGR, was significant only in the PEG treatment. The latter QTL, where the ‘Akihikari’ allele acts as a favorable allele, was co-located with a QTL for transpiration rate (water use/shoot biomass). In contrast, no QTL for water use efficiency (WUE; biomass production/water use) was co-located with those for RGR. This study demonstrated that the physiological aspects and genetic control of rice grown under water stress condition could be quantified even in the absence of a root system. Our results showed that of the shoot-related traits, transpiration rate was more important than WUE on drought resistance under hydroponic culture. The favorable ‘Akihikari’ alleles would be useful for further genetic improvement of upland cultivars including the widely grown, deep-rooted elite cultivar ‘IRAT109’. We will determine the relationship of transpiration characteristics to osmotic adjustment function under water stress.

P 5.38 - Root morphology of drought tolerant and drought sensitive maize genotypes

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One important strategy to adapt plants to drought-stress environments is to improve the efficiency of the root system for water uptake. In areas with an early, intense precipitation, followed by no further rainfall for several weeks, a phenotype with rapid vertical root growth may access deeper water sources and thus avoid drought. The objective of this study is to evaluate the difference among genotypes for vertical root growth and its relation to drought tolerance. For this purpose, two drought sensitive (Ac7729/TZSRW and SC-Malawi) and two drought tolerant inbred lines (Ac7643 and CML444) are evaluated. Two approaches are used to assess the root morphology: i) the root growth up to the 2-leaf (V2) stage on wet paper in pouches and ii) the vertical distribution of the root length density at the 5-leaf (V5) stage in 80 cm growth columns, filled with quartz sand. The pouch system was chosen to facilitate a fast, non-destructive and repeated measurement of root growth. However, this system does not allow for an evaluation of the most important root type of maize, the nodal roots. Therefore, the sand system was chosen to enable the measurement of the initial root morphology and rooting depth of the nodal root system. All root traits are measured with the digital image processing software WinRhizo (Regent Instruments INC., Canada). The suitability of the two systems to study the root morphology of a large numbers of genotypes, which is a prerequisite for a QTL mapping approach, is discussed.
P 5.39 - Physiological characteristics related to drought resistance in Chinese local wheat cultivar Hongmangmai

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Hongmangmai is a typical local wheat (Triticum aestivum L.) cultivar cultivated under rainfed conditions in the southern Loess Plateau, which is known to be drought resistant. However, the relationships between its drought resistance and assimilation or accumulation of assimilates are still unknown. In order to characterize the drought resistant mechanisms of Hongmangmai, the relative importance of pre- and post-anthesis assimilates to grain yield, and flag leaf and ear photosynthesis were investigated under irrigated and non-irrigated conditions and compared with Japanese cultivar Haruhikari sensitive to drought. Water stress reduced grain yield of the two cultivars, but Hongmangmai was less affected by water stress than Haruhikari. Remobilization of pre-anthesis assimilates and its contribution to the grain yield were decreased by water stress in Hongmangmai but increased in Haruhikari. However, the net photosynthetic rate (Pn) of ear and flag leaf during post-anthesis was significantly higher and less affected by water stress in Hongmangmai than in Haruhikari. The rate of reduction in stomatal conductance was similar for the two cultivars, but intercellular CO2 concentration in the flag leaf of Hongmangmai was lower than that of Haruhikari in non-irrigated treatment. No differences were observed in leaf water potential (Ψ) and osmotic adjustment of the flag leaf of the cultivars. It was therefore suggested that the main physiological factor associated with drought resistance in Hongmangmai was attributed to the capacity for chloroplast activity in the flag leaf at low leaf Ψ, which apparently allowed sustained Pn of flag leaf during post-anthesis under water stress.

P 5.40 - Evaluation of physiological traits for identifying key components of drought tolerance in wheat

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Wheat is Australia's most important cereal crop. It is mainly grown on rainfed areas, where available moisture is a primary constraint on wheat production. The central objective of this research is to investigate physiological responses of wheat varieties to drought and identify physiological traits which enable wheat varieties to maintain yield under South Australian drought conditions. First results from a growth room experiment were obtained using a completely randomized design (CRD) with five replications per line. One drought tolerant line and one intolerant line were cultivated in plastic pots (15 cm diameter, 40 cm high) containing 8 kg of a soil-sand mix (50:50). The five watering regimes were: well-watered (field capacity), droughted at -5 bar (6.9% water available), -5 bar and re-watered, -15 bar (wilting point) and re-watered at -15 bar. The water stress was imposed 40 days after planting by withholding irrigation for the drought treatments. The overall amount of water consumption per plant per day was determined (pots were weighed and watered daily). Relative water content of leaves, chlorophyll content (SPAD meter) and chlorophyll fluorescence (PAM-2000) was measured on the last fully expanded leaf. Leaf surface temperature (IR-Thermometer), biomass, relative root mass, harvest index and grain yield were also measured. Preliminary data suggested that the chlorophyll content of the tolerant line increased with increasing drought severity whereas the chlorophyll content of the intolerant line decreased with increasing drought severity. The responses of the other physiological parameters will be discussed in relation to harvest index, biomass, root mass and grain yield.
P 5.41 - High temperature tolerance at anthesis in rice (O. sativa)

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In future climates, high temperature episodes are likely to be much more frequent. If these episodes coincide with sensitive stages of development, such as anthesis in rice, then yields will be reduced due to increased spikelet sterility. Greater heat tolerance at anthesis will therefore be needed as an adaptation strategy. The effect of high temperature episodes (35 °C and 38 °C for 6h) on spikelet fertility of eight rice mapping population parents, with N22 as a check, was studied in controlled environments. Plants were exposed to high temperature on the 2nd day of anthesis and spikelets opening during the period of exposure marked, to exclude any spikelets escaping exposure to heat. Genotype N22 was the most tolerant with 91 and 64% spikelet fertility at 35 ° and 38 °C, respectively. Among the mapping population parents, Bala was the most tolerant (41% fertility at 38 °C) and Azucena the most susceptible (3% at 38 °C). 123 F6 RILs of Bala X Azucena were then screened for heat tolerance at 41±1 °C using the same protocol. Of the 123 RILs, 88 had 0-10%, 27 had 11-20%, 4 had 21-30% and 4 had 31-40% spikelet fertility. Spikelet fertility in Bala was 38%. Screening is currently being repeated, prior to identifying QTLs for true tolerance to high temperature.

P 5.42 - Evaluation of near-isogenic introgression lines of rice for grain yield and physiological traits under a range of drought stress conditions

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Rice (Oryza sativa L.) is very susceptible to drought. Genetic studies of drought resistance in rice have been undertaken in order to identify quantitative trait loci (QTL) of primary and secondary traits associated with drought resistance. The QTLs for deep and thick roots were previously identified in doubled haploid population of Azucena/IR64. Introgression of genomic segments carrying these QTLs into an elite rice variety, IR64 was practiced through marker-aided selection. A set of IR64 near-isogenic lines (IR64-NILs) for deeper and thicker roots were earlier developed and selected 57 IR64-NILs with their parents were used for the experiment conducted in the dry season at Chum Phae Rice Experimental Station in northeast Thailand in 2002. The line-source sprinkler irrigation was used to generate a non-stress treatment (control) and 4 levels of drought stress conditions occurring during the reproductive stage through maturity. Genotypic variations for grain yield and physiological traits were examined. In all drought stress conditions, grain yield was significantly different among IR64-NILs. Grain yield of IR64-NILs was reduced linearly with a reduction of water levels. When water stress was not severe in which yield loss was less than 50%, grain yield obtained from those water stress conditions were associated with potential yield and flowering time under non-stress condition. Under severe stress in which yield loss was more than 50%, genotypes with higher grain yield, had larger filled grain number (r = 0.719 **) and less spikelet sterility (r = -0.591 **). Higher grain yield of IR64-NILs was associated with higher leaf water potential at predawn (r = 0.390 **) and midday (r = 0.568 **), which that resulted in having lower leaf rolling score (r = -0.576 **) and higher panicle exertion rate (r = 0.535 **). The results have been shown that several secondary characters have been likely to be associated with higher yield in drought stress conditions. However, some of them may not always contribute to high grain yield under different drought stress conditions, and higher grain yield of genotypes may or may not cause by a contribution of root systems. Only the IR64-NILs that possess appropriate drought resistance characters can be produced higher grain yield under water limiting conditions.
Drought stress is the most common abiotic constraint for stable barley production in Morocco. A key factor for sustainable development is the ability to understand and utilize the mechanisms of germplasm adaptation to dry land conditions, defined as the ability of a genotype to sustain an acceptable yield level under stress. The objective of this study is to understand the physiological processes underlying, barley domestication and adaptation to drought. To reach this objective, 192 entries and 4 checks of Diverse Barley Germplasm (DBG), including both landraces and improved cultivars, representing different breeding periods were tested under dry and irrigated conditions. The study was conducted during 2003/04 season at INRA Research Experiment Station at Sidi El Aydi (31° 15' N, 7° 30' W), near Settat, Morocco. Rainfall during this cropping season was 323.6 mm. The traits measured were grain yield phenology, spectral reflectance indices, chlorophyll concentration, chlorophyll fluorescence parameters, canopy temperature. Data showed that yield varied widely among genotypes. A significant negative correlation between the number of days from sowing to flowering and final grain yield was observed indicating a negative effect of late maturing trait on final grain yield. Among spectroradiometer traits determined, single ratio trait (SR) was more discriminative than normalized difference vegetation index (NDVI) in differentiating genotypes. The genotype by trait biplot reveals the interrelationships among barley traits. It also provides a tool for visual comparison among genotypes on the basis of multiple traits. This biplot, explained 52% of the total variation of the standardization data. This relatively low proportion reflects the complexity of the relationships among the measured traits. The largest variation explained by the biplot came from grain yield (GY), under rainfed and irrigated conditions, and from single ratios (SR) under two water regimes, as indicated by the relative length of their vectors. The most prominent relations revealed by the biplot were a strong negative association between grain yield and canopy temperature depression (CTD) and by single ratios and canopy temperature depression, as indicated by the large obtuse angles between their vectors. Normalized difference vegetation index (NDVI) and water index (WI) were not discriminative among barley genotypes. The heavy rainy conditions at the end of the growing season hampered the development of stress under rainfed conditions.

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This study aims to illustrate the main eco-physiological and agronomical characteristics observed in salt-tolerant varieties of durum wheat and chick-pea. These species fit two different plant model. The durum wheat is a cereal crop, with determined flowering, retained tolerant to the salinity, while the chick-pea is a grain-legume, with indeterminate flowering, sensitive to salinity. In the case of wheat, the characteristics associated with the varietal tolerance to the salinity are: 1) a shorter growing season and earlier senescence 2) a higher pre-dawn leaf water potential 3) a stronger osmotic adjustment 4) a better maintenance of the number of productive stems per plant 5) the aptitude of maintaining the yield standard and increasing the water use efficiency. These characteristics correspond with those of drought-tolerant durum wheat varieties. In the case of chick-pea, the characteristics associated with the varietal tolerance to the salinity are: the longer crop cycle the ability to produce new leaves and flowers when a saline stress occurs the ability to create a large biomass by catching up the aptitude of maintaining the yield standard and increasing the water use efficiency the ability of maintaining a high nitrogen fixation under slightly saline conditions. These characteristics have been often associated with the chick-pea varieties sensitive to the terminal drought. In the case of the durum wheat the varietal characteristics associated with the drought or with the salt tolerance are similar. Different is the chick-pea behaviour: the characteristics associated with the salt tolerance have been commonly described for those varieties which are sensitive to the terminal drought. The conclusions of this study give useful insights for identifying the salt tolerant varieties.
Among legumes, faba bean (*Vicia faba* L.) is considered sensitive to drought. Lack of available soil moisture frequently constrains its production worldwide. Several field-based screening methods have been used for drought tolerance, but selection solely based on grain yield is generally slow and of limited value for genetic improvement in the desired physiological traits as different resistance mechanisms have expression under different environments. Therefore, more efficient screening methods are needed for the development of drought-tolerant cultivars and a component of the coordinated “EUFABA” research programme focuses on this need. To determine variation in physiological traits related to drought tolerance in faba bean, a pot experiment was established in a growth chamber using six inbred lines of diverse genetic backgrounds. Plants were grown at adequate moisture supply (20% w/w) for 41 days. Then moisture stress was induced in half of the pots by gradually decreasing water application from field capacity (20% w/w) to moisture stress (2-4% w/w). Measurements were taken during the course of water stress.

As expected, relative water content (RWC) significantly declined (76 to 70%) when moisture stress was induced. More importantly genotypes varied significantly in their RWC; ILB 938/2, BB 686 WN/1 and Mélodie maintained higher RWC than 332/2/91/015/1 and Victor/2. Moisture stress influenced osmotic potential in all genotypes except ILB 938/2, with Victor/2 showing the maximum decline. ILB 938/2 and Melodie had relatively higher stomatal resistance than 332/2/91/015/1, ILB 2282/2 and Victor/2 at adequate water supply. Stomatal resistance increased when plants were subjected to water stress, with ILB-938/2 being most responsive and 332/2/91/015/1 the least. Differences in leaf temperature among genotypes were noted even under well-watered conditions; leaf temperature recorded in ILB 938/2 was higher (16.6 °C) than in 332/2/91/015/1 (15.2 °C) and this is in agreement with their stomatal response. Shoot dry matter production showed that ILB 938/2 was more water-use efficient than line 332/2/91/015/1. The results indicate that ILB-938/2, a drought-tolerant genotype, had higher stomatal resistance than sensitive line 332/2/91/015/1, effectively minimizing water loss and avoiding dehydration. Relatively lower leaf temperature in 332/2/91/015/1 compared with ILB-938/2 verified genotypic response to stomatal characteristics, as open stomata with higher transpiration generally results in a cooler canopy. Therefore, among physiological attributes stomatal resistance and leaf temperature may serve as rapid indicators of drought tolerance for faba bean improvement.
P 5.46 - Comparative physiology of rice and wheat under drought

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Rice is used as a model cereal to study drought response at the molecular level, with the goal of applying results to other cereals through comparative genomics. To assess the relevance of results from rice to other species, we compared the kinetics of drought development and plant response of tolerant and susceptible tropical rice and sub-tropical wheat cultivars. Stress was imposed on pot-grown plants at six different stages, with rice grown at 29/21 °C and wheat at 22/18 °C. Water was withheld until pots reached 30% field capacity (FC) or leaf wilting was observed, and then reapplied. Rice reached 30% FC after 9 days and wheat after 13 days. Before rewatering, both species reached leaf water potentials of -1.2 MPa and similarly low transpiration rates. Stress reduced leaf relative water content to 54% in rice and 72% in wheat, while leaf membrane stability declined to 55% in rice and 78% in wheat. In both crops, water stress before heading delayed flowering and reduced yield, but yield decline in rice was more severe than in wheat. Stress after heading did not affect yield. Rice and wheat showed similar responses to timing of drought stress, with early stages of reproductive development being most susceptible. The natures of differences between tolerant and susceptible cultivars were similar for the two species. Our results indicate that this type of experiment can provide meaningful samples for comparative genomic studies, but differences in crop adaptation must be considered. Relevance of these findings to field-grown plants remains to be established.

P 5.47 - The involvement of proteolytic activities in the proline response of osmotically stressed canola leaf tissues

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In order to establish the importance of osmotic induced proteolysis on the proline accumulation process, we used canola leaf explants subjected to osmotic, already described as a potent proline accumulating system. Proteolysis activity as well as free amino acids, total protein and Rubisco contents were quantified according to stress duration. Proline accumulated represented more than 70% of the free amino acids (6% of total dry matter) and took place at the expense of the other amino acids. A negative correlation was found between protein and proline contents that suggests a truly massive transfer between these two nitrogen pools. Furthermore, decrease of total protein and Rubisco contents are concomitant. Although an inhibition of the protein synthesis is observed, proteolytic activities have been shown to be stimulated in response to osmotic stress. Thus, aspartic acid, cystein and serine proteases participate to this activity as revealed by the use of specific inhibitors. The osmotic induced proteolysis seems to be an organized and controlled process. For instance, an osmo-dependant transcriptional regulation of the expression of three genes (LCS7, bcp15 and BnSAG12-1) encoding cystein proteases and of one gene (pkd425) encoding an aspartic acid protease was also demonstrated. In addition, Bnd22, encoding a serine protease inhibitor, is highly stimulated and would be able to limit the proteolytic response. In conclusion, under osmotic stress conditions, proline accumulation reflects a metabolic adjustment of the amino acid pools issued in part from protein degradation.
P 5.48 - Association mapping for root characteristics in durum wheat

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Roots play a pivotal role in the adaptive response of crops grown under conditions of limited water availability. Little information is available as to the chromosome regions responsible for the control of root characteristics in wheat. At DiSTA, we have started investigating root characteristics in a collection of 134 durum wheat accessions assembled for allele mining and genetic association study purposes. A preliminary profiling with 70 SSRs showed the presence of a high level of long-range linkage disequilibrium, even after accounting for the population structure (Maccaferri et al. 2005, Mol. Breed. 15:271-289). The objective of this study was to evaluate root traits at the seedling stage in a representative subsample (57 accessions) of the collection. Plants were grown in an agar medium contained between glass plates. The following traits were considered: root number, root length, shoot length, root angle, root and shoot dry weight. Significant differences were detected for all traits thus indicating that this collection of accessions has a rather broad genetic basis and can be exploited for further studies to investigate the genetic basis of root architecture in durum wheat. Significant effects on root traits (root angle, length of the primary seminal root and number of seminal roots) due to linkage disequilibrium were detected for a number of markers on different chromosomes. Although the validity of these preliminary findings awaits validation through the analysis of a second set of different accessions, our results are encouraging as to the possibility of utilizing association mapping for identifying chromosome regions influencing root characteristics in durum wheat.

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P 5.49 - Evaluation at two water regimes of the effects of the major QTL root-ABA1 influencing root architecture and ABA concentration in maize

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Backcross-derived lines (BDLs) have been developed for a major QTL affecting leaf ABA (L-ABA) in maize. The BDL evaluation validated the effect of the QTL on L-ABA and showed a significant effect also on root traits (Landi et al. 2005, Mol. Breed. 15:291-303), suggesting that the QTL primarily affects root architecture and size which, in turn, influence L-ABA and other traits. For this reason, the QTL has been named root-ABA1. Our objective was to evaluate the effects of root-ABA1 in testcross combination. One set of BDLs (high/ high L-ABA and low/low L-ABA) was crossed with 13 lines mainly from China. The 26 testcrosses were tested under well-watered and drought-stressed conditions in China. On average, the yield of the well-watered and drought-stressed treatments were equal to 211 and 75 g/plant, respectively. The testcrosses with the high-root-ABA1 allele showed a significant decrease in vegetative biomass (-10%), total biomass (-9%), ears/plant (-9%), harvest index (-2%), kernel weight (-1%), kernels/plant (-8%) and grain yield (-9%). Our results confirm the model suggested in Landi et al. (2005): the high-root-ABA1 allele, as compared to the low-root-ABA1 allele, was postulated to decrease grain yield through a reduction of fertility due to an increased ABA production at the root level consequent to a larger and more superficial root system. Our findings are in accordance with such model, also in consideration that the yield of the high-root-ABA1 testcrosses was more negatively affected under drought conditions (-15.5%) as compared to well-watered conditions (-7.7%). The positional cloning of root-ABA1 is in progress.

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P 5.50 - Reaction of different sugar beet genotypes to short-term water deficiency

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The objective of this work was to assess differences in reaction of nine sugar beet genotypes (g), previously evaluated in the field according to their reaction to water deficiency, to short-term drought stress. Plants were grown in pots with soil/sand mixture in a glasshouse, and watered daily. After 90 days, water was withheld completely for 5 days to induce the stress. Sugar beet g differently responded to experimental conditions. Visually, g85 and g95 lost leaf turgescence the most, while g125 and g45 did not wilt. Dry matter % increased significantly in shoots of g25, g45, g55, g65 and g85, and in roots of g25, g55, g65 and g85. The shoot/root DW ratio reduction under water deficiency, universal way of plant adaptation to drought, occurred in g65, g85, and g125. Better reflection of solar radiation from leaf surface or lower chlorophyll content may reduce heating, while increase in stomatal diffusive resistance may reduce water loss through transpiration. In g45, g75 and g125, which contained more chla+b and carotenoids than the other genotypes, drought provoked significant decrease in pigment's content, while in g25, g55, g65 and g85 the effect was the opposite. Under drought, the chla/b ratio increased and chla+b/car ratio decreased in all genotypes, but the changes were the smallest in g125, g45 and g55. Stomatal diffusive resistance significantly increased in g25, g45, g55 and g85, and leaf soluble proline content in g25, g65 and g85. Genotypes that showed the smallest changes in analysed parameters may be considered as more tolerant to water stress (g125, g45, g65).

P 5.51 - In situ staining of sugars in Sporobolus stapfianus, a desiccation-tolerant plant accumulating sucrose during water stress. An informative technique for sugar localization in plant tissues using tetrazolium and "coupling" enzymes

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The build up of carbohydrates during dehydration stress is thought to be a very important mechanism for the acquisition of desiccation tolerance. Sporobolus stapfianus (a C4 plant), similar to other desiccation tolerant plants, is shown to accumulate sucrose during water stress. As photosynthesis rapidly declines during water stress, starch has been hypothesised to be a major carbon source for sucrose accumulation. Despite the importance of sucrose accumulation in the acquisition of desiccation tolerance, little is known about the concurrent breakdown of starch. Moreover, nothing is known about the cellular localization of either the sucrose or hexose pools inside the leaf. The present study proposes an original, simple and selective method for in situ localization of sucrose and glucose. The detection of sucrose and glucose in the leaf is based on coupled enzymatic reactions (sucrose phosphorylase, EC 2.4.1.7 + PGM, EC 5.4.2.2 + G6PD, EC 1.1.1.49 for sucrose detection; HK EC 2.7.1.1 + G6PD, EC 1.1.1.49 for glucose) leading to the formation of NADH with the subsequent reduction of iodonitrotetrazolium (INT) giving the red-colored insoluble INT formazan. The present study shows that there is an increase in sucrose content until 47% relative water content and that starch breakdown only accounts for 1/3 of the required carbon for sucrose accumulation. The staining for glucose shows intensive coloration of the vascular bundles at the beginning of water stress. Sucrose staining shows uniform coloration of all leaf compartments: bundle sheet cells, mesophyll cells and epidermal cells.
P 5.52 - Ammonium metabolism during dehydration stress in the "resurrection" plant *Sporobolus stapfianus*. A comparison between desiccation-sensitive older leaves and desiccation-tolerant younger leaves

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Desiccation-tolerant plants ("resurrection" plants) represent a unique model for the study of metabolism in response to dehydration stress. During desiccation stress, many protective mechanisms interact leading to the acquisition of desiccation tolerance. *Sporobolus stapfianus*, similar to other resurrection plants, undergoes general nitrogen reorganization during dehydration stress (proteolysis, increase in free amino acid content and protective proteins, chlorophyll loss, upregulation/maintenance of important enzymes). Nitrogen metabolism is therefore strongly involved in the desiccation process. To date nitrogen metabolism has never been investigated in "resurrection" plants. Since the metabolism of ammonia is integral to nitrogen metabolism, the present study will focus on ammonium metabolism during desiccation stress. Interestingly, in *Sporobolus stapfianus* the younger leaves are desiccation-tolerant (DT) whereas the older leaves are not able to acquire desiccation tolerance during dehydration stress (desiccation-sensitive, DS) and don't survive rehydration. In making possible the comparison between DT and DS leaf material, *Sporobolus stapfianus* is an ideal model to understand the metabolism of desiccation tolerance. This study will analyse the differences in DS and DT ammonium metabolism speculating about the links between leaf aging and desiccation tolerance. Attention will be focused on the activity of the various enzymes involved in ammonium metabolism, including GDH (EC 1.4.1.2) aminating and deaminating activity, and GS (EC 6.3.1.2) activity.

P 5.53 - Growth and accumulation of organic and inorganic solutes in two canola cultivars during water stress

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Responses of 20 day-old plants of two *Brassica napus* L. Cultivars SLM046 and Zarfam to water period [5 (control), 10, 15, 20 day] were examined. The drought tolerant line SLM046 had significantly higher fresh and dry masses of shoots, and seed yield than drought sensitive line Zarfam in 15 and 20 day. The effect of water stress on reduction in total leaf soluble sugars was markedly greater in SLM046 as compared to Zarfam. No effect of water stress was observed on leaf soluble proteins but there was a slight increase in total free amino acids of both cultivars. Leaf Proline content increased markedly in both cultivars and SLM046 has greater Proline content than Zarfam at all water period. Water stress had no significant effect on seed oil content and Erusic acid content of seed oil, however, content of glucosinolates in the seed meal increased and Zarfam had greater content of glucosinolates than SLM046.
**P 5.54 - Effect of different air and root-zone temperatures on growth of annual medic**

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Annual medic are the most commonly grown forage legume in Ley-farming systems. However, its lack of persistence under severe winter and early spring conditions reduced its utilization in cold zones of the world. Cold tolerance has been shown to be the most important factor in winter and early spring survival. Selection for cold tolerance is difficult due to the complexity of field evaluation. A method of selection performed under environmentally-controlled conditions has been used for the identification of genotypes having superior cold tolerance. Three annual medic cultivars (Medicago polymorpha cv Santiago, Medicago radiata cv Radiata, and Medicago rigidula cv Rigidula), were evaluated for traits under three levels of day/night air temperatures (DNAT, 15/10, 20/15 and 25/20 ±0.2 °C) and four root-zone temperatures (RZT, 5, 10, 15 and 20 ± 0.2 °C). The experimental design was a 3 * 3 by 4 factorial with treatments organized following a randomized complete block design with three replications. The result showed that M. rigidula and M. polymorpha were the best cultivars for leaf, stem and root dry matter, plant height, leaf and stem to root ratio, leaf to stem ratio, leaf number and leaf area at low and moderate RZT, respectively. At low RZTs (5 and 10 °C) and high DNAT (25 °C) M. rigidula produced the most stem node number, leaf number, leaf area, leaf dry matter, stem dry matter and leaf to stem ratio. Thus M. rigidula performed well at low RZT and high DNAT and probably the most promising for the production of herbage at low temperature.

**P 5.55 - Water relation, growth and osmotic adjustment in sorghum seedlings under PEG 6000 and NaCl in light and darkness**

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The effect of PEG 6000 and NaCl treatments on growth, water content, FW, DW and soluble sugar level in 3d-old seedlings of sorghum bicolor Jambo were studied. Under these stress conditions, RWS and W of seedlings decreased dramatically. Subsequently this reduction resulted in the markable decrease in FW of different parts of stress imposed seedling. On the contrary, a substantial increase in DW was observed. Furthermore, a considerable increase in the sugar levels in different plant parts was detected. The fructose level was always higher than that of the glucose and sucrose in response to various treatments. The stressed light grown seedlings showed an elevated content of sugars in comparison with dark grown seedlings. Based on these studies, a possible relation ships between seedling growth, water content and soluble sugar content in relation to various a biotic stresses were discussed.
P 5.56 - Effects of drought stress on ecomorphophysiological traits of Zea mays L.

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In order to study of the effects of water stress on physiological and morphological and ecological traits of zea mays L. (S. C. 704), two experiments were conducted at the research institute of forests and Rangelands under control growth chamber and green house. The experimental design were applied in germination on water stress was CRD with 6 levels of PEG6000 (0 = control, -0.1, -0.3, -0.6, -0.9, -1.1 Mpa) and four replication. The second experiment design were applied in estabilished wa ter stress was CRD with 4 levels of water period (4, 8, 12 and 16 day) and four replication. In the first experiment seeds were placed in petridishes that Irrigated with different mentioned levels of PEG6000. After 15 days, seed lings shoot and root lenght, Dry weight and leaves number were measured. In the second experiment, the seeds were sown in a pot and nourished with Hogland solution until the plants were established. During 70 days each level of water period in the pots irrigated. The following traits were measured on plants, root, shoot and total length and dry weight, leaves number, water potential ($\Psi_w$) of leaves, relative water content (RWC), water saturation deficit (WSD), chlorophyll a, b and total, a/b ratio, caroten rate, total soluble sugar, (TSS) and proline concentration of plants were measured. The results showed that the water deficit decreases the percent & speed of seed germination, length of shoot and weight of the plants, $\Psi_w$, RWC, a, b and total chlorophyll and increases, length of root, WSD, TSS and proline rate of the plants. The highest amount of carotene in the plants was produced at water period of 12 day and the lowest was produced water period of 4 day.

P 5.57 - Ecophysiological analysis of drought tolerance in some populations of Medicago polymorpha (L.)

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The amount of water available to agriculture in Algeria is declining because of increasing population pressure and drought incidence during the last decades. Therefore, in order to enhance our phylogenetic resources and to select better adapted populations of Medicago able to provide livestock feeding and optimise the water use despite drought conditions, six populations of Medicago polymorpha (L.) have studied. The effect of water stress during the blooming stage on leaf area, relative water content, accumulation of organic solutions (solublesaccharides and praline) and on pod production showed several responses among studied populations.
P 5.58 - Interaction between chickpea cultivars and rhizobial strains to enhance legume growth under water deficit

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Legumes in symbiosis with rhizobia are very important for human and animal nutrition, and the rehabilitation of marginal lands. However, this association is very sensitive to environmental stresses mainly water deficit responsible for land degradation and crop yields decline in the arid areas. Water stress affects symbiosis at different stages, mainly nodule metabolism. It is required for biochemical activities by all known life form and, its deficit affect nodule metabolic activities. In the present work, four strains of the Mesorhizobium and the Sinorhizobium genera were tested for their symbiotic effectiveness with four cultivars of chickpea under water deficit. Experiment was performed on hydro-aeroponic medium, under controlled conditions. Water deficit was applied by adding 50 mM Manitol. Statistical analyses showed that M. ciceri reference strain (835) was the most efficient with the four chickpea cultivars (Amdoun, Beja, Kasseb and Chetoui) under unstressed conditions. Under water deficit, even the manitol application had drastic consequences on all symbioses; those implicating M. ciceri strain seemed to preserve the best performances. The use of one efficient local strain of M. mediterraneum (C11) with the analysed cultivars showed high tolerance of the symbioses to water deficit, whereas an other inefficient M. mediterraneum strain (48.2) lead to a drastically affected symbioses by water deficit. The bacterial partner seemed to be an important factor that affects all analysed parameters under water deficit. Analysis of nodule antioxidant enzymes showed that under water stress, nodule antioxidative defence seemed to be assured by peroxidases (POX, EC 1.11.1.17) and APX (EC 1.11.1.11) activities. Some isozymes of POX appeared to be more concerned than others in this process.

P 5.59 - Drought tolerance in cutleaf medic (Medicago laciniata L., Mill): a morphological and physiological perspective

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Drought is one of the serious problems limiting productivity of crops. Problems of water shortage and population pressures are ceaselessly increasing, dictating the need for greater productivity from limiting and subsidiary resources. Progress in breeding for drought tolerance has been slow due to the complexity of the traits and the massive environmental influence. Our studies attempted to provide insights into important traits associated with tolerance to drought in one genotype of cutleaf medic that is able to grow in very dry areas of Iran with average rainfall lower than 170 mm per year. Drought substantially reduces dry matter (yield) of sensitive genotypes affecting most yield attributes. Tolerant genotype had significantly higher root-shoot ratio, plant height, and lower leaf area under stressed condition that reduced water consumption by plants. Tolerant genotype had higher cation concentration including [Mg], [Zn], [K], [Ca], [Fe] as well as organic solutes like proline, soluble sugars and proteins in leaves with increasing stress levels; Also they showed higher RWC, Ψw, Chl a and b; lower Ψs, lipid peroxidation, elevated levels of reduced ascorbic acid and better osmotic adjustment (OA). Therefore, tolerance to drought stress seem to be involve a plethora of adaptive strategies including morphological and physiological characteristics like less leaf area, plant height, and greater root-shoot ratio, higher RWC due to better OA and greater partitioning of K, Mg, Ca, Zn in leaves along with higher production of organic solutes, proline, sugars and proteins and the up-regulation antioxidant system.
P 5.60 - Linking crop growth to soil water in bambara groundnut (Vigna subterranea L., Verdc) using C\textsuperscript{13} discrimination

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Bambara groundnut is an important tropical legume that serves as a cheap source of protein for poor families in sub-saharan Africa. It is a drought tolerant crop and this makes it a suitable crop to grow in the semi-arid regions where water is usually in short supply. An experiment was conducted in controlled environment glasshouses between 2000 and 2003 to investigate the possibility of using carbon isotope discrimination ($\Delta$) to study the physiological responses of bambara groundnut to soil water. The experiment involved three landraces (S19-3, DipC and UN from Namibia, Botswana and Swaziland, respectively) and two watering regimes in a randomised complete block design with four replicates. The two watering regimes were: a fully irrigated control that was irrigated weekly to 90% field capacity and a drought treatment which was not irrigated from 49 days after sowing (DAS) until final harvest at 147 DAS. Carbon isotope discrimination ($\Delta$) of the three landraces ranged between 17.1 and 20.1%, with the values being higher in the irrigated treatments compared to drought treatments. Significant positive relationships were found between $\Delta$ and TDM, pod yield, HI and $e_w$, which indicated that there could be a potential of using $\Delta$ as a selection criterion for some physiological traits in bambara groundnut breeding programmes.

P 5.61 - Evaluation of ground cover, grain filling and seed germination of two lentil (Lens culinaris Medick.) varieties under normal and drought stress conditions

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In order to evaluate water deficit and plant densities effects on ground cover, grain filling and germination of two varieties of lentil, a field and a laboratory experiment were carried out. The field trial as split plot factorial based on randomized complete block design include two irrigation regimes (full and until flowering as five and one times irrigation) in main plots and three densities (40, 80 and 120 plant/ m\textsuperscript{2}) and two varieties (Ziba from microsperma and Local of ahar from macrosperma type) in subplots with 4 replications. The seed germination and seedling growth of both varieties at water potentials between 0 and –14 bars by using PEG 6000 were tested. The plant densities and drought stress had no significant effects on seed vigor. The Maximum ground cover (MGC) and grain weight (MGW) were achieved by full irrigation and 120 plant/ m\textsuperscript{2}. The Ziba cultivar at all densities produced MGC at 78 and 64 days after planting in five and one times irrigation, respectively. At all plant densities, the ground cover of two irrigation treatments had lower difference at primary growth stage, but it was increased across growing period. The water deficit at grain filling period was reduced effective filling period and MGW significantly. At both varieties, an increase in water stress decreased germination percentage, germination rate, normal seedlings percentage, seedling dry weight, and root and shoot length of seedlings. The tolerance threshold of Ziba and local Ahar for 20% loss in NS% were –0.15 and –1.7 bars, respectively.
P 5.62 - Influence of different irrigation times on grain yield and some traits of two soybean (Glycine max L.) varieties

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In order to evaluate irrigation time on yield and some characteristics of two varieties of soybean, a field experiment was carried out. The trial was split plot based on randomized complete block design, included four irrigation regimes (T1 = 60±3, T2 = 80±3, T3 = 100±3, T4 = 120±3 mm water evaporation from pan class A as irrigation times) in main plots and two varieties (hac and zan) in subplots with 3 replications. The soybean grain yield at T1, T2, T3 and T4 were 82.6, 47.4, 45.7 and 32.9 g/m², respectively. The grain yield at T1 treatment had significant difference with other irrigation regimes, whereas, the difference between T2, T3 and T4 were not significant. The biomass of hac (254.088 g/m²) was higher than zan (217.152 g/m²), significantly. The soybean plants under different irrigation regimes showed different plant biomass and number of nods include pod. The irrigation treatments had no significant effects on harvest index. The mean of harvest index for T1, T2, T3 and T4 were 26.17, 19.17, 19.5 and 20.3%, respectively. Variety of Hac (23.1%) had greater harvest index than zan (20.5%). Delay irrigation caused drought stress effects on soybean and decreased biomass, grain yield, harvest index and number of nods include pods, pods and seeds per plant. Therefore, irrigation with short time interval and low water volume is better than irrigation with long time interval and much volume in soybean production.

P 5.63 - Effects of water stress on Sicilian olive cultivars

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Water stress can negatively affect the productivity of olive groves growing in the Mediterranean area (Giorio et al. 1999). The selection of the most resistant cultivars can result in greater productivity. We have investigated the changes in some physiological parameters of different olive cultivars (Olea europaea L., cv. Biancolilla, Nocellara del Belice and Giarraffa) widely grown in Sicily. The effect of water stress on relative water content, daily leaf water potential and stomatal conductance was investigated in three-year old trees grown in pots. Water stress can cause oxidative stress (Smirnoff 1998), and the regulation of the antioxidant system is an important mechanism to avoid this kind of stress. At the end of the water stress treatment, the activity of superoxide dismutase (SOD) and peroxidase (POD) was assayed in leaves of control and treated plants of the different cultivars. The data obtained show significant differences in the effects of water stress on the three cultivars tested, indicating Biancolilla as the most resistant cultivar and Giarraffa as the most sensitive one.

P 5.64 - Drought network in Slovakia: interdisciplinary approach to study crop drought tolerance

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In the contribution the network of scientists has been presented who are dealing with integrated and multidisciplinary study of plant drought tolerance covered by the research project “Climate change and drought in Slovakia: impact and scopes for sustainable agriculture, quantity and quality of production”. The project topic includes long-lasting research at the 3 study levels: molecular-whole plant, whole plant – canopy, ecosystem – region. The key aspects of the projects are focused on the study of regulation mechanisms of crop drought tolerance improvement, testing the selection criteria and evaluation of cereals, leguminoses, sugar-beet, fruit trees, vegetables, grasses and weeds, but also wild and ornamental plant species’ drought resistance. In evaluation of the impact of drought in crop production the combination of destructive and non-destructive methods have been used to detect environmental stress and vulnerability of canopy plants to stress. Besides the biological aspects, the ecological and crop farming aspects have also been successfully incorporated into the study project, which are related to plant nutrition, soil properties and farming technology analyses improving water management during crop growth-production process. The project has integrated biologists, breeders, ecologists, climatologists, producers and technologists. Undoubtedly, the climate change rise will induce new ideas and leads in Europe and all over the world for which we are offering our research potential.

P 5.65 - Understanding lupin responses to water deficit and yield improved under terminal drought

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Narrow-leafed lupin (Lupinus angustifolius L.) is the most important grain legume crop grown on the acid sandy soils of the Mediterranean climatic region of southern Australia. Lupin crops are grown during the cool wet winter months on current rainfall and mature during the spring as temperatures and evaporation rates rise and rainfall decreases. Consequently, the reproductive growth of the crop is shortened by terminal drought resulting in a reduction and variability in seed yield. Selection has ensured early flowering in narrow-leafed lupin. However, the subsequent vegetative growth of the apical branches often delays the start of pod filling until terminal drought develops. Pod filling is almost entirely dependent on current assimilation and photosynthesis in narrow-leafed lupin is very sensitive to water deficits. Pod filling is reduced by a reduction in the availability of current assimilate, that induces pod and seed abortion and reduces harvest index. We have compare the yield of lupin genotypes under both average and extreme conditions of terminal drought and have identified high yielding genotypes. Characteristics conferring better yield under terminal drought have been identified and evaluated in order to provide selection criteria to help breeders to develop narrow-leafed lupin cultivars that tolerate terminal drought.
P 5.66 - Drought response QTLs in a DTP maize mapping population growing in pots

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A maize composite population called Drought Tolerant Population (DTP) was created at CIMMYT by pooling several stocks known to perform well under drought. This population was further selected through several cycles for improved yield under drought by CIMMYT and the Maize Research Institute, Belgrade. From this improved DTP population an inbred line was extracted (DTP79) and crossed with the drought susceptible inbred B73 to make a mapping population. F3 progeny from the cross were trialled in a glasshouse experiment in pots under gradually increasing drought stress. The pots were covered to prevent evaporation. Every 2-3 days leaf extension and pot weights were recorded to determine leaf area growth and plant water use. Plants at the 6-7 leaf stage were sampled for physiological traits, water status, shoot and root weights, and soil water content was measured. Major QTLs for water-use efficiency were identified on chromosome bins 3.09, 6.00, 8.06 and 9.00, with increasing alleles contributed by both parents. QTLs for soil water extraction showed DTP79 alleles to allow more soil water to be extracted (bins 9.00, 9.06), though both DTP79 and B73 alleles contributed to QTLs for root dry weight (bins 2.08, 3.04, 3.05, 9.02). The DTP population before and after selection for high drought yield was screened with 88 RFLPs and SSRs. Several markers showed variation in allele frequencies between the populations and some of these coincided with QTLs for drought responses in the mapping population, particularly the QTLs for root weight on 3.04, and soil water extraction on 9.06.

P 5.67 - Evidence for an endogenous ABA to IAA balance controlling growth of excised orchid roots (Catasetum fimbriatum) under osmotic stress

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It is well known that both IAA and ABA inhibit root elongation. However, low IAA level is necessary for cell expansion and an accumulation of ABA is necessary to maintain root elongation at low water potentials. Endogenous levels of IAA and ABA were measured by means of HPLC-ELISA in excised root of C. fimbriatum (Orchidaceae) incubated at 25 ± 2 °C with 16 h fluorescent light at 40-50 μmol.m-2.s-1 for five weeks on solidified Vacin and Went medium added with 1, 2, 4, 6, 8 and 10% sucrose, as well as with 2% sucrose plus mannitol to the equivalents osmotic potentials. The maximum root growth occurred concomitantly with a moderated osmotic stress in media with 4% sucrose or 2% sucrose plus mannitol. Both the endogenous levels of ABA and IAA increased following the osmotic stress. Although ABA accumulation in roots under osmotic stress is well documented (our results showed an inverse correlation, with r = - 0.99, between relative water content and ABA levels) these organs are not considered a preferential site for IAA biosynthesis. Using radiolabeled tryptophan we have shown that C. fimbriatum roots have the capacity to synthesize IAA and its conjugates. A direct correlation between root elongation and the endogenous ABA/IAA ratio in incubated roots (r = 0.80) were observed. We hypnotized that an optimal ABA/IAA ratio could promote root elongation by enhancing the positive effect of auxin in organ elongation and minimizing its negative effect (e.g. ethylene accumulation, which is inhibit by ABA).
P 5.68 - The effects of rain exclusion on carbon uptake of tree seedlings of the Amazonia Rainforest

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In climate change scenarios for Amazonian forest a decreased in precipitation is predicted. Drought events are expected to increase in frequency and intensity. At our study site (Brazilian Amazonian forest), two one-hectare plots, one with a rain exclusion structure to mimic drought (Plot B) and a control plot (Plot A) were used to simulate a dry climate scenario. We studied four canopy tree species in the seedling stage: shade tolerant seedlings (Pouteria sp. and Manilkara huberi), opportunistic seedlings (Vouacapoua americana) and light dependent seedlings (Sdrolobium paraensis). At the end of the dry season, the low values of stomatal conductance and the low pre-dawn leaf water potentials observed in all species indicated that they were experiencing some degree of drought stress during the dry season. Amax values of all species (except Vouacapoua americana) presented lower values in plot B than in plot A, suggesting a limitation on carbon assimilation by the rain exclusion. In plot A, the species with highest Amax and gs max was Sdrolobium paraensis (light demanding species) but in plot B, this species showed the lowest values of Amax and gs max. These first results for the end of the dry season suggest that if the predicted climate change for NE Amazonian forest area occurs, some functional groups will be more affected than others.

P 5.69 - Study of endogenous free polyamine accumulation and ethylene evolution in mungbean cultivars grown under water stress

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Effect of water stress at different stages of plant growth on total dry weight (TDW), relative water content (RWC) and changes in arginine decarboxylase (ADC) activity, total free polyamines and ethylene content were studied in two cultivars of Mungbean (Vigna radiata (L.) Wilczek). RWC and TDW declined in both the cultivars under water stress during vegetative and flowering stages while ethylene content increased. During vegetative stage, there is a significant increase in ADC activity on day three and while recorded a decrease during reproductive stage. Drought imposed during vegetative stage induced significant increase in free polyamine content on 3 day and further prolonging the stress up to five days resulted in sharp decline and recorded lesser than the control plants and lasted even after re-watering. At the onset of stress, there is a significant increase in Spd and Spm content (on day three) but later decreased significantly and followed similar trend as that of free polyamines, during the same time Put concentration increased 2-fold (on day five). In contrast to vegetative stage, during reproductive stage the cultivars recorded that at the onset of stress there is an increase in Put content and decline in Spm and Spd content. However, the decline in Spm content was very high compared to Spd content. In both the cultivars, as the leaf ages, Spd and Spm, ratio of Spd+Spm/ Put and Spd+Spm/total polyamine declined., while at the same time Put content, ratio of Put/ Spd and Put/ Spm increased.
P 5.70 - Effect of drought stress on ecophysiological characteristics of sweet almond (Prunus amygdalus L. Batsch). I. Gas exchange, content of photosynthetic pigments, and chlorophyll fluorescence

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Plants of Prunus amygdalus were submitted to different levels of drought stress induced by polyethylene glycol 6000. Effects of drought stress on gas exchange rate, chlorophyll contents (Chls a and b), and chlorophyll fluorescence parameters were investigated in order to know the resistance of P. amygdalus to this kind of stress. Significant decreases due to drought stress for gas exchange per unit of leaf area were in transpiration and CO₂ assimilation. Content of photosynthetic pigments in leaves of almond plants at low (-0.5 MPa) and moderate (-1 MPa) drought stresses were similar to control plants. Effects of drought stress on functioning of both photosystem (PS1 and 2) were monitored. In this case initial fluorescence (F₀) did not change till osmotic potential of nutrient solution reached -1.5 MPa (severe stress level). Maximal photochemical efficiency of PS2 (Fv/ Fm) and non-photochemical quenching (qₙ) were affected by severe drought stress.

P 5.71 - Stem photosynthesis in three different almond species during drought and subsequent recovery

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Prunus dulcis (Miller) D.Webb (bitter almond) and two wild almond species, P. lycioides (Spach) C.K.Schneider and P. scoparia (Spach) C.K.Schneider, are all three native species to Iran. The three species mentioned are used as rootstock, but only P. dulcis serves as a rootstock for commercial almond (P. dulcis) production. These three species are found on different ecological habitats in Iran. P. scoparia and P. dulcis grow in the most and least drought susceptible places, respectively. In a greenhouse these almond species were subjected to drought stress induced by PEG6000 for two weeks, followed by three weeks of recovery. Drought treatments consisted of a control treatment (osmotic potential of the nutrient solution (Ψₛ) = -0.1 MPa), and three drought stress levels (Ψₛ = -0.6, -1.2 and -1.8 MPa, respectively). In a former experiment (Rouhi et al. 2005), it was found that P. scoparia lost all its leaves as a reaction to drought. This loss of leaves was only observed for P. lycioides for the highest stress level, whereas P. dulcis always kept some physiological active leaves. Therefore it was assumed that stem photosynthesis plays a major role in the carbon budget of P. scoparia. Chlorophyll concentrations indeed revealed the highest concentrations in P. scoparia. Also gas exchange measurements at the stem level showed a positive net stem photosynthesis, whereas net stem photosynthesis always remained negative for P. dulcis and P. lycioides. In drought stress conditions stem photosynthesis is an important feature to survive, and to maintain a positive carbon balance.

P 5.72 - Variation of deep rooted ability in rice genotypes in savanna/woodland of West Africa

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In West Africa, upland is still the major ecosystem of rice culture. Droughts of short and long duration as well as low capacity of soil to hold available moisture often reduce grain yield. There are two major ways to achieve drought resistance in rice plant. One is drought avoidance and the other is drought tolerant. It is said that drought avoidance has advantage characteristic with extending root to drought according of dry matter production for rice plant. In this study, we analyzed deep rooted ability among different rice genotypes in Oryza sativa L., O. glaberrima Steud. and interspecific progenies (NERICA) in the different environmental condition of Côte d’Ivoire and Guinea. On the other hand, the development of the simple drought evaluation system is important to develop a resistant rice variety. Then we developed the evaluation system through the relationship between leaf temperature and stomata resistance. In the report, we will express about some characteristics of rice drought avoidance with deep rooted ability and the new evaluation system on drought resistance of rice in the savanna/woodland of West Africa.

P 5.73 - Is drought stress resistance important under irrigation? A case study for two olive varieties in Tunisia

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Two olive (Olea europaea L.) varieties, Picholine and Meski, were intensively studied during Autumn 2004, under irrigated conditions in Tunisia. Plants were irrigated according common irrigation practice applied in the orchard. Plant-water relations were investigated by: (1) thermal dissipation sap flow sensors on stems and branches, (2) leaf water potential measured by a pressure chamber, (3) stomatal resistance by a diffusion porometer, (4) transpiration and (5) photosynthesis both measured by a gas exchange equipment. Besides these ecophysiological characteristics also some other parameters were measured like (6) leaf thickness and (7) stomatal size and density. Sap flow was calculated according to Do & Rocheteau (2002a, b), which yielded better results than the original approach of Granier (1985). First results indicate that the diurnal courses of stomatal resistance, and the stomatal characteristics are similar for both varieties. However, the response of these stomata to e.g. internal CO₂ concentration differed, indicating a different internal leaf resistance for CO₂. The diurnal course of leaf water potential was closely linked to that of transpiration and sap flow through branches. Water consumption over the experimental period was highest for Meski. The leaves of Picholine showed a higher degree of succulence, indicating a higher water storage capacity. Water storage in stem and branches seems to be highest for Picholine. At this moment it can already be stated that both varieties are showing differences in regard to their plant-water relations, whereby Picholine seems to be most drought tolerant and most interesting variety even under irrigated conditions.

P 5.74 - Ecophysiological differences of three almond species to drought and subsequent recovery

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Prunus dulcis (Miller) D.Webb (bitter almond) and two wild almond species, P. lycioides (Spach) C.K.Schneider and P. scoparia (Spach) C.K.Schneider, are all three native species to Iran. The three species mentioned are used as rootstock, but only P. dulcis serves as a rootstock for commercial almond (P. dulcis) production. These three species are found on different ecological habitats in Iran. P. scoparia and P. dulcis grow in the most and least drought susceptible places, respectively. In a greenhouse these almond species were subjected to drought stress induced by PEG6000 for two weeks, followed by three weeks of recovery. Drought treatments consisted of a control treatment (osmotic potential of the nutrient solution (ψs) = -0.1 MPa), and three drought stress levels (ψs = -0.6, -1.2 and -1.8 MPa, respectively). It was found (Rouhi et al. 2005) that P. scoparia lost all its leaves as a reaction to drought. This loss of leaves was only observed for P. lycioides for the highest stress level, whereas P. dulcis always kept some physiological active leaves. At the end of the experimental period, new leaves were only formed for P. lycioides, having net photosynthesis rates which equalled those of the control plants, while for P. dulcis values were only half those of the control treatment. Internal CO2-concentration indicated that non-stomatal limitations depressed photosynthetic rates for P. scoparia, which resulted in overall leaf loss for this species. Only P. dulcis and P. lycioides seem to suited to be used as rootstock for commercial almond production.


P 5.75 - Genotypic variability for tolerance to drought of N2-fixing common bean (Phaseolus vulgaris)

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Common bean (Phaseolus vulgaris L.) is a major source of protein in the developing world, but plant growth and yield are often reduced by various environmental constraints. Drought is the major limitation for grain legumes yield, especially when the plant growth depends upon N2 fixation. The enhancement of bean productivity requires the development of drought-tolerant symbiosis. Exploration of the variability in drought responses would permit not only to identify some tolerant genotypes, but also to determine useful criteria for genetic improvement of drought tolerance. The aim of this study, which is included in this approach, was to investigate the effect of water stress on plant growth, N2 fixation and water relations in four common bean lines: COCOT, originated from local population, BAT477, BRB 17 and Flamingo from Colombia. After germination, seedlings were inoculated with a reference (Rhizobium tropici CIAT 899) or local (Rhizobium gallium 8a3) strain, and grown in a glasshouse on nutrient solution with or without 50 mM of Mannitol. Plants were harvested after 4 weeks of water stress. Measured parameters were growth, nodule development, and symbiotic nitrogen fixation (SNF) as well as tissue water and proline contents. Results show a genotypic variability for responses to water stress: Flamingo was the most tolerant line, whereas COCOT was the most sensitive, the other lines occupied an intermediate position, independently of the bacterial partner. The relative tolerance of Flamingo seems to depend on its ability to maintain an adequate leaf area insuring an important carbon supply permitting the development of an abundant and efficient nodular system, which in turn determines an important rate of SNF and permits the plants to conserve their growth potentialities.
P 5.76 - Identifying and understanding the key factors that play a major role in the plant productivity under water stress conditions

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At CIMMYT, we are studying drought tolerance using a broad based approach that spans phenotyping and QTL detection through to functional genomics and genetic diversity studies. We are exploring the genetic response to drought at flowering in tropical maize. Our target genotypes are parents Ac7643 (tolerant) and Ac7729/ TZRW (susceptible) and six segregating genotypes from this cross. These are grown in replicated trials in Mexico under stress and well watered conditions. Target tissues are silks, ear tips and ear leaves. Over the past three years representative samples (40 individuals) have been harvested in the field for each genotype under different water regimes. This material is currently being used for functional genomics work and quantification of key metabolites (e.g. carbohydrates, ABA and osmolytes). Sets of genes and metabolic pathways important to the adaptation to water stress have been identified using publicly available maize microarrays. Results are available over three years and across field replicates. Our results show a consistency of response across field replicates indicating a good sampling methodology. Using these results, real time RT-PCR is currently being used to examine gene expression over more timepoints. Suitable methodological approaches have been developed from this research in order to provide recommendations to others who wish to conduct similar studies of drought tolerance. Results from functional genomics will be presented as part of the larger multidisciplinary approach adopted at CIMMYT with examples showing the linkages between these data and other data produced by this project, such as gene-QTL co-localization.

P 5.77 - Drought stress in potatoes - consequences and selection possibilities

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In Central Europe drought limits the growth and the development of many cultivated plants to an increasing degree. It is known that also the potato reacts relatively sensitive to water deficit. Drought stress induces, depending on the stress intensity and the physiological conditions of whole plants, various changes in their metabolism. Amongst the accumulation of so-called compatible solutes especially the nitrogenous compounds show a marked variation in their concentration and activities. Changes in yield, yield stability and quality of the tubers are a consequence. In order to prove possible correlations a test assortment of potatoes was investigated. For that, bud cuttings of 23 ideotypes were cultivated in the greenhouse in pots containing a soil mixture. After a cultivation of about 7 weeks leaves from these plants were detached and incubated in a buffer solution containing PEG to simulate drought stress. The concentrations of different nitrogen fractions were analysed. In order to determine the yield reduction and the quality of the tubers under stress water was kept away for 2 weeks. After rewatering, plants were cultivated comparably with the control variant up to harvest. Under these conditions yield was reduced by 25-90% and the characteristics of quality showed significant differences between stress and control. Furthermore, correlations between nitrogen fractions (tubers and leaves), quality parameters and the yield under stress could be observed.
P 5.78 - Water deficit stress effect at filling seed stages of rapeseed
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The last irrigation time is important for producing high yield. The objective of this study was to evaluate suitable time for rapeseed last irrigation. Four last irrigation time including of end of silique formation, initiation of siliques color changing in main stem, 10% siliques maturity in main stem and 20% siliques maturity in main stem as main plots and three cultivars including Orient, Okapi and SLM046 as subplot were arranged in a split plot design based on RCBD. Phenological, morphological and agronomic characteristics were recorded in three regions for two years. The result showed that last irrigation time and cultivar had significant effects on oil content and yield at 1% probability. Last irrigation at 10 and 20% siliques maturity set as a same group for yield with Duncan’s test. They produced the highest yield and oil seed content among treatments. Yield stability of SLM046 were the most among cultivars, because the siliques number was not descended much. Water deficit at silique formation reduced silique number in plant and yield. Last irrigation at the end of silique formation for SLM046 and 10 or 20% siliques maturation in main stem for Okapi were the best time for last irrigation to produce the highest oil yield. There were positive correlation between plant height and seed per silique, silique per plant and seed weight, oil seed content and seed yield and biologic yield, seed yield and biologic yield and harvest index. If there is not enough water, it is better the last irrigation is done at changing of silique color on main stem.

P 5.79 - Water deficit stress at developmental stages of rapeseed
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The objective of this study was to study water deficit effect at developmental stages of rapeseed. Six water deficit levels including of normal irrigation, no irrigation from germination to rosset, no irrigation at stem elongation, no irrigation at flowering, no irrigation at silique formation and no irrigation at seed filling as main plot and three cultivar including of Hyola 308, PF7045.91 and SLM046 as sub plot were arranged in a split plot design based on RCBD. Seed yield, phenological, morphological and agronomic characteristics were recorded two years. The result showed that irrigation had significant effect on yield and yield component at 1% probability. When plants were exposed on water deficit at flowering stage, the silques number were decreased, significantly. However, no irrigation at stem elongation had no effect on yield and yield components. There are high correlation between yield and silque number and total dry matter. Hyola 308 in normal irrigation (4556 kg/ha) and SLM046 at no irrigation at flowering (1895 kg/ha) had the highest and the lowest seed yield, respectively. PF7045.91 in no irrigation from germination to rosset and Hyola 308 in no irrigation at stem elongation, no irrigation at silque formation and no irrigation at filling stage had the highest seed yield in comparison with other cultivars.
Role of antioxidant system in leaves and roots of two Eucalyptus globulus clones with different sensitivity to drought

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The role of antioxidant system in leaves and roots of two Eucalyptus globulus clones with different sensitivity to drought. Under normal growth conditions, the production and destruction of reactive oxygen species (ROS) is well regulated in plant cells. However, under environmental stress, the balance between the production of ROS and the quenching activity of the antioxidant system may be upset. Although the antioxidant system of tree species has been studied in relation to some environmental stresses such as high altitude, pollution and low temperature, few studies have focused on the activity of such systems in eucalyptus plants, in particular looking at the response to water deficits. Taking into consideration that some regions in which eucalyptus is grown, e.g., southern Portugal, experience hot dry summers, the investigation of antioxidants as a protective system in E. globulus deserves special attention. The aim of this work was to compare the performance of two Eucalyptus globulus clones with different sensitivities to drought (ST51 is considered more sensitive than CN5) in terms of their metabolic response to water deficit. With respect to osmotically active compounds, osmotic potential, total protein and antioxidant enzymes (glutathione reductase, ascorbate peroxidase, catalase and superoxide dismutase), we considered the response of leaves and roots of the two eucalyptus clones to a slowly imposed water deficit. An important finding of the present study is the metabolic response of roots to drought. Whereas the activity of GR is undetectable in roots of well-watered plants, it shows a dramatic increase under water stress, suggesting that glutathione reductase plays a more important role in root protection of E. globulus under drought, as compared to CAT and SOD.

Evaluating sterility trait in F2 population of drought lines using molecular tools in the target environment

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With aim to associate, yield and drought with minimum sterility, locally drought tolerant variety NDR 97 and another popular drought tolerant variety Nagina 22 (N-22) were first independently evaluated for sterility, yield and RWC. NDR 97 which possess deep root system had low sterility (1 to 10%), yield base 21-30 g/plant and 76% RWC. On another had, N-22 which has high germination capacity (>90%) and carbohydrate content leading to better regeneration capacity had 81.4% RWC, yield base 10 to 12 g/plant and >10% sterility. These morphometric traits were also evaluated in dry and wet seasons under natural condition. Total protein profile of seed of both donors were also studied in normal and after subjecting to drought (PEG treatment (-10 bar) for 96 h). In both cases new protein bands of low KDa appeared but unlike N-22, NDR 97, loss of high molecular weight protein were also observed. This may help in further monitoring characteristic related to NDR 97 in the segregating populations while evaluating yields and low sterility. Following this a cross of NDR 97 and N-22 have been made to combine better traits of drought in NDR 97 from N-22. This cross is being also evaluated for above parameters. Parallely F1 is being advanced to F2 generations. Here sterility as well as drought parameters will be evaluated. We will also use some earlier reported molecular markers specifically for drought linked to yield and also for TGMS. Over all this study will lead us to develop a most promising drought lines having less sterility with better yield.
P 5.82 - Changes and adaptations of metabolic response systems during drought stress in Amaranthus (wild spinach)

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Germplasm of this traditional vegetable crop was screened for metabolic changes and traits of tolerance during drought stress. Different physiological, morphological and biochemical traits of drought tolerance were investigated, including enzymes of the anti-oxidative pathway (SOD, AP and GR), turgor maintenance (LWP, RWC), membrane stability (CMS, TTC), osmoprotection (proline), early drought tolerance and leaf area. Useful traits of drought tolerance were identified in *Amaranthus tricolor*, *A. hybridus* and *A. hypochondriacus*, and these selected screening techniques are currently being applied in a breeding program in an attempt to select, improve and develop tolerant genotypes of the neglected vegetable and seed crops that could contribute to secure food production in rural areas in Africa and the rest of the world.

P 5.83 - Partial root drying: changes in resources partitioning improves fruit quality

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Partial rootzone drying (PRD) technique, a novel approach to watering and irrigating crops, was developed on the basis of knowledge of root-to-shoot signaling in drying soil. The aim of the presented paper was to investigate the effect of the PRD treatment on tomato plant and fruit growth, fruit yield and water use efficiency. In addition to investigation of assimilate partitioning between fruits and rest of the plants, measurements of dry weight and dry weight distribution were done. Tomato plants were grown in compost with the root system divided equally between two plastic pots. During the experimental period, half of the root system of PRD plants were exposed to drought, while the remainder of the root system was irrigated. After c.10 days the treatment was reversed. Control plants received the same amount of water on both sides of the root system. Obtained results showed that as a consequence of PRD treatment the growth of leaves and stems was reduced, as well as the number of flower trusses, WUE was increased, although the effects on root and fruit biomass, fruit diameter and yield were not significant. Differences in biomass distribution and increased ratio of fruit DW to leaf DW supported the view that changed assimilate partitioning (from shoot to fruit) might explain different PRD effect on shoot and fruit growth and increased water use efficiency in PRD treated plants.
P 5.84 - Study of germination, photosynthesis and antioxidative enzymes in cotton phenotypes (Gossypium hirsutum L.) under simulated drought stress

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Laboratory and greenhouse experiments were conducted to evaluate the germination response, net photosynthesis, and the activity of antioxidant enzymes (catalase (CAT) and ascorbate peroxidase (APX)) of four cotton phenotypes (determinate, semi-determinate, and indeterminate with normal and Okra leaf shapes). For germination study, four levels of PEG 6000 (-0.3, -0.5, 0.75 and -1 MPa) solution and for greenhouse study, three levels of field capacity (-0.25, -0.5, -0.75 FC) were used. Control treatment was used in all experiments. Results showed that among cotton phenotypes, germination percentage of indeterminate phenotype with Okra leaf shape was the highest in all PEG treatments. Likewise, this phenotype had the highest fresh and dry weight. In greenhouse study, Super Okra cultivar with indeterminate phenotype had the highest leaf area index and dry weight at all drought treatments. At higher levels of drought stress (-0.5 and -0.75 FC), Super O kra cultivar while at the lower drought treatments Deltapine 50 (indeterminate with normal leaf shape) exhibited the highest net photosynthesis. For catalase activity, Oultan cultivar (determinate phenotype) and Shirpine 603 (semi-determinate phenotype) had the most activity. In contrast to catalase, Super Okra cultivar had the highest activity of ascorbate peroxidase. Likewise, its activity was significantly higher (0.95 units/mg protein) than control (0.52 units/mg protein). The results of this study indicated that Super Okra cultivar had better performance under drought conditions which can be attributed to higher net photosynthesis and ascorbate peroxidase activity.

P 5.85 - Water use efficiency and carbon isotope discrimination in Brazilian soybean cultivars under water stress

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Water use efficiency (WUE), or transpiration efficiency, is well known to closely relate with dry matter production under drought stress in many plants and crops. It can be applicable as a varietal screening criterion for drought tolerance, but the direct measurement of WUE in field is not possible. In C₃ plants, the relationship of WUE and carbon isotope discrimination (CID) has been empirically documented and physiologically elucidated. A pot experiment was conducted in Tsukuba, Japan, in summer of 2004, with precise and regular measurement of the amount of supplied and transpiring water for the estimation of WUE of soybean (Glycine max L. [Merr.]) cultivars from Brazil under well-watered and water-stressed conditions, as well as instantaneous WUE (WUEᵢ) in several occasions. Leaf samples were collected of the youngest fully expanded trifoliolate and analyzed for δ¹³C values by an IRMS, which were then converted to CID (Δ) with use of -8.00o‰ as the δ¹³C of the air. Under well-watered condition, WUE was ranged from 2.7 to 3.3 g L⁻¹ and significantly higher in Conquista (drought-tolerant), as compared with BRS-183 (tolerant), BRS-185 and Aurora. WUE was apparently increased to be around 3.4 g L⁻¹ in all cultivars by water stress from the beginning of flowering for 25 days. Δ of well-watered Conquista leaves was significantly lower (17.7%) than other cultivars (around 19%). Under the water stress, Δ decreased to be from 17.2 to 17.9% for all cultivars. There was a negative linear correlation (r² = 0.929) between WUE and Δ, so that it would be reasonable to estimate WUE in field-grown soybeans with the measurement of Δ for its application to drought screening.
P 5.86 - Does osmotic adjustment increase the yield of chickpea under terminal drought?

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Variation in osmotic adjustment among chickpea (Cicer arietinum L.) genotypes has been observed when exposed to terminal drought. However, in one study this was associated with yield while a second study showed no association with yield in water-limited environments. In the present study, parents differing in osmotic adjustment were crossed and a set of recombinant inbred lines developed. A method was developed to measure the osmotic potential at full turgor in up to 200 lines on the same day. The variation in osmotic adjustment during podding was measured under terminal drought in the F₂, F₃, F₇ and F₈ generations. Yields were measured in the F₈ generation. Osmotic adjustment in chickpea appeared to be under the control of several genes, was shown to be poorly inherited and no benefit to yield was observed when measured in the field under terminal drought. Some of the deficiencies in the methodology for measuring osmotic adjustment in multiple samples will be also discussed.

P 5.87 - Discovery of a chromosomal region associated with root structure using a set of representative cultivars derived from rice germplasm collections

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Asian cultivated rice (Oryza sativa L.) holds genetic diversification of root systems to adapt to diverse water stress conditions. Although several QTLs conferring length and thickness of roots have been identified, the genetic mechanism of other traits related to root morphology and structure has remained unknown. This study deals with the microscopic observation of root structure using a core collection and the association between variation of root traits and genotypes at RFLP marker loci mapped on 12 chromosomes. A core collection was recently established based on multivariate analysis of genotypes at 147 RFLP marker loci. A total of 66 representative cultivars consisting of 51 Indica and 15 Japonica rices were selected as a core collection from 332 germplasm accessions which cover global geographic distribution. Microscopic observation showed the similarity of frequency distribution for root area and number of xylem vessels between Indica- and Japonica-type cultivars. Japonica rice was more variable than Indica rice in root traits such as areas of stele and xylem vessels, xylem vessel area/no. ratio, and stele/root area ratio. In particular, stele/root area ratio in Japonica rice showed bimodal distribution corresponding to small and large ratios. Based on the association between alleles at marker loci and variation of stele/root area ratio, we discovered a particular region on chromosome 4 harboring stele/root area ratio. This chromosomal region also involves putative QTL responsible for root thickness as reported previously. Further analysis will be focused on fine mapping of QTL controlling stele/root area ratio on chromosome 4 using F₂ and backcrossed populations and their progeny lines.
Recent advances in drought research at ICRISAT: Using root traits and rd29a:DREB1A to increase water use and water use efficiency in drought-prone areas


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Drought is responsible for the loss and instability in yield of many crops grown by resource-poor farmers of the semi-arid tropics. Groundnut genotypes with higher transpiration efficiency (TE, in g of biomass per kg of water transpired) were found. Several surrogate traits have been efficiently used as indirect selection criteria such as specific leaf area (SLA), specific leaf nitrogen (SLN), SPAD chlorophyll meter reading (SCMR), and delta 13C. Mapping populations involving contrasting parents for TE have been developed and phenotyped. The identification of molecular markers linked to genes controlling TE is in progress. The possibility to improve TE by using rd29a::DREB1A transgenics of the groundnut variety JL24, appears also possible. Transgenics had lower stomatal conductance under well-watered conditions than JL 24. Under progressive soil drying, the transpiration began to decline at a lower soil moisture level in the transgenics than in JL 24. Two events had consistently 50% higher TE values than parent JL24. Besides improving TE, deep and profuse roots for water mining are essential components of drought avoidance. Chickpea yield under drought was correlated with high root length density (RLD) and high RLD in deeper soil layers under severe terminal drought. A screening of the ICRISAT’s chickpea mini-core collection indicated a large variation in for RLD and root depth. QTL for root traits are being identified. Current efforts at ICRISAT are to use comparative genomics and physiology to understand the role of roots in traits related to drought tolerance in sorghum and pearl millet.

P 5.89 - Drought-related responses in juvenile material of eucalyptus: endogenous aba content in sensitive and resistant genotypes

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Eucalyptus globulus is one of the most economically important species in forestry because of its high growth rate and superior pulp properties. Nutrient limitations or drought decrease potential productivity, but different strategies to survive to adverse circumstances or in sites with marked seasonal drought are present in certain trees, which allow profitable plantations in unfavourable conditions. In this work we studied some drought-related responses of two half-sib natural populations of this species differing in their tolerance to drought stress; a drought-sensitive population (MG 26/16470 provenance Moogara, Tasmania, Australia), and a drought-resistant population (JN1/16319 provenance Jeeralang North, Victoria, Australia). Stress symptoms in sensitive plantlets were manifested by a rapid loss of turgor in the shoot apex and the first pair of leaves followed by the death of the plant, whereas drought-resistant genotypes maintained the shoot apex turgid in detriment of older leaves, which were dropped. Therefore, it seems that maintaining an undamaged apex for a long time would increase drought resistance in longer or more severe stress. Strategies for drought avoidance also dealt with higher endogenous content of abscisic acid (ABA) and its derivative ABA-glucose ester (ABAGE) in the resistant genotypes, not only in well-watered conditions (controls), but also in stress-watered periods. Moreover, differences in other morphological parameters, such as smaller leaves decreasing transpiration rates, or a more developed root system, was shown in the resistant population which might contribute to a higher water use efficiency.

This research was carried out with financial support from ENCE (Asturias, Spain), contract CN-02-112-B1. Plant material was kindly donated by ENCE (Asturias, Spain).
P 5.90 - Chlorophyll fluorescence and photosynthetic efficiency in different genotypes of Beta vulgaris L. in relation to yield and stomata conductivity under drought stress and non-stress conditions

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Variation of chlorophyll fluorescence can use as an index in evaluation of plant tolerance to physiological and environmental stress. In this order an experiment was conducted at Karaj in 1999. Research was carried out in factorial based on RCBD with 3 replications. Drought and non-drought stress treatments with 9 sugar beet genotypes were randomized. Results showed that Fo was higher in stress than non-stress conditions. Photosynthetic efficiency or Fv/Fm was significantly reduced in stress conditions (P < 0.05). Fm was higher in stress than non-stress conditions (P < 0.05). Fv was lower in stress conditions (P < 0.05). Genotypes had not significant difference (P < 0.05). Genotype had significant difference in Fv/Fm (P < 0.01). Fv/Fm reduced in stress and genotypes means showed lower Fv/Fm in stress. As Fv/Fm has a high correlation with photosynthetic quantum yield therefore in genotypes with lower Fv/Fm, there was more sensitive photosynthetic system under drought stress. There was not significant correlation between Fv/Fm and root yield. Results showed that there was positive correlation between photosynthetic efficiency (Fv/Fm) and stomata conductivity but it was not significant for top and down of leaf at the 5% level of probability. It found that as stomata conductivity reduced in stress conditions, photosynthetic efficiency also reduced because of lower exchanges of gases specially CO₂.

P 5.91 - Study of proline variations in related to abscisic acid, stomatal conductivity, plasma membrane stability in different genotypes of Beta vulgaris L. under drought stress and non-stress conditions

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Effect of drought stress was studied on proline accumulation in sugar beet (Beta vulgaris L.). An experiment was conducted at Karaj and Mashhad in 1999 use a factorial design based on RCBD with three replications. Nine genotypes of sugar beet were examined in this experiment. Treatments were stress (50 days non irrigation in early growth period) and non-stress. Results showed that sugar beet leaves under drought and non-drought stress produced proline but it increased as stress increased (P < 0.01). Effect of genotypes on proline accumulation was significant at the 1% level of probability. There was negative correlation between root yield and proline content in fresh leaf (P < 0.05). Plasma membrane stability also decreased in drought stress and this reduction was significantly correlated with increase of proline content (P = 0.01). There was not significant correlation between proline content and abscisic acid. Correlation between relative water content (RWC) and leaf proline content was not significant.
P 5.92 - Drought stress tolerance in wheat by image analysis of micro-morphological traits

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The need to realize appropriate yields in hot-dry environments is an old, but always actual, challenge of researchers particularly for wheat, one of more important cereals economically. Nowadays this challenge is carried out by all the scientific knowledge available in agronomic research. The present study talks about micro-morphological characterization of anatomic structures by image analysis system connected to microscope. This system is able to realize all the measures of anatomic structures easily and it investigates their involvement in giving drought-tolerance feature to durum wheat. Five Italian varieties of Triticum durum Desf. were analyzed. They were grown in three environments that were rainy different during vegetative cycle in the 1989-90 cropping season. The vascular system was analyzed in the first and last internode (peduncle) and in flag leaf, in this leaf the stomatic apparatus was also analyzed, for a total of 59 parameters. The obtained data were subjected to analysis of variance – one-way ANOVA (2 factors: 3 locations x 5 varieties), mixed model; therefore the variation sources that resulted significant were undergone to a mean multi comparison test and the significance were tested with the Duncan test. All parameters were also submitted to correlation analysis (Pearson Correlation Analysis). Many parameters have showed interesting positive and negative associations, even with agronomic features such as production, 1,000 seeds weight and hectoliter weight. The varieties recorded values significantly different between them, both for their genetic characteristics and for their different reaction rule in the three different cultivation climatic environments. This particular type of analysis, carried out only on micro-morphological traits of wheat plant, was able to characterize durum wheat varieties that adapt better to the difficult water stress conditions, ensuring satisfying yields.

P 5.93 - Effect of water availability on biomass accumulation and leaf area expansion of durum wheat grown under Mediterranean conditions

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Crop Dry Weight (CDW) and Leaf Area Index (LAI) were determined in irrigated and rainfed field experiments, and subsequently contrasted to water balance differences in experiments conducted with 25 durum wheat genotypes in 1997 and 1998. The water received by the crop in 1998 was 13 and 23% lower than the previous year in the irrigated and rainfed sites, respectively. Differences in CDW and LAI between irrigated and rainfed experiments were proportional to the differences in their water balances the two years. The reductions in both growth indices caused by drought were significantly higher the second year of experiments, probably because crop growth was enhanced by a better distribution of the water available in 1998. However, when measured as a percentage, the differences between irrigated and rainfed experiments in CDW and LAI were similar for the two years, suggesting that unlike water distribution, it did not affect the reduction caused by drought in relative terms.
A greenhouse study compared the effects of partial rootzone drying (PRD) and regulated deficit irrigation (RDI) on split-rooted tomato plants. Plants were grown in pots with their root system separated equally between two soil compartments and exposed to three irrigation treatments, i.e. Control (Tc) receiving 100% of plant transpiration; PRD receiving 50% Tc on half of the root system while the other half was left to dry, and alternating sides weekly; RDI with 50% Tc supplied equally to both sides of the root system. Leaf relative water content and water potential decreased sharply in RDI-treated plants, while the PRD plants exhibited relatively higher values. Stomatal conductance was more affected under RDI than under PRD. The A/Ci curves showed that PRD and RDI did not have any effect on photosynthetic capacity. In fact, the values of the photosynthetic parameters $A_{\text{max}}$, $J_{\text{max}}$, $V_{\text{cmax}}$, $J_{\text{max}}$ to $V_{\text{cmax}}$ ratio, and $R_{\text{d}}$ were not significantly influenced by the irrigation treatments. Both PRD and RDI induced a reduction in plant transpiration and vegetative biomass, but resulted in an overall increase in water-use efficiency under PRD and RDI. Data from a field experiment confirmed those obtained in the greenhouse, and showed higher fruit numbers per plant in Tc compared to PRD and RDI, but fruit diameter was significantly increased under PRD compared to control and RDI treatments. It is concluded that the application of PRD irrigation technique may reveal suitable for horticultural crops under water scarcity scenarios. However, more agronomical testing is required before recommending the application of such techniques on a wider scale.

Desiccation-tolerant or ‘resurrection’ plants provide unique model systems to investigate metabolism in response to desiccation stress. There is strong evidence that in monocotyledonous species Sporobolus stapfianus Gandoger (Poaceae), desiccation tolerance is dependent on the induction of various protective mechanisms during dehydration, including the accumulation of carbohydrates and amino acids. In S. stapfianus it is evident that following the decline in photosynthesis, there is a significant and simultaneous increase in both sucrose and amino acid (including proline) content. This may suggest an intricate co-ordination of the flux of carbon skeletons between the accumulation of sucrose, amino acids and respiration. An analysis of regulatory enzyme activities is proposed to provide important information as to whether or not there is a co-ordinated simultaneous increase in the key enzymes functioning in these respective pathways. Preliminary results indicated an upregulation of ATP dependent phosphofructokinase and pyruvate kinase, which control glycolytic carbon flux into respiration, concomitant with the increase in sucrose and amino acid content. A more thorough analysis of the latter together with sucrose phosphate synthase activity (responsible for sucrose synthesis) and glutamine synthetase activity (intricate to amino acid biosynthesis) will be presented.
**P 5.96 - Drought tolerance response in wild barley, Hordeum spontaneum to ecological stress at "Evolution Canyon" microsite, Israel**

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Wild barley, Hordeum spontaneum, the progenitor of cultivated barley (Hordeum vulgare), is widespread across the Near East Fertile Crescent and eastern Mediterranean regions. Occupying diverse habitats ranging from mesic Mediterranean to desert in Israel, wild barley exhibits variation in various traits due to its richness in adaptive diversity. Caryopsis primary dormancy is an extremely important survival strategy of *H. spontaneum* in the Mediterranean climate. In this study, we demonstrate the relationship between the dormancy depth and seedling drought tolerance of this species at three sites of “Evolution Canyon” at lower Nahal Oren, Mount Carmel, Israel. The south-facing slope (SFS) presents the xeric and warmer habitat; the north-facing slope (NFS) presents the mesic and cooler conditions; and the ecological factors at the bottom of the canyon are between the SFS and NFS. The inter-slope distance is 100 m at the bottom and 400 m at the top. The obtained results showed that caryopses from SFS had significantly deeper dormancy than those from the NFS. Moreover, the seedling revival ability after periods of drought was also significantly higher in caryopses collected from the SFS than from NFS sites, whereas the dormancy and seedling revival ability at the bottom of the canyon showed an intermediate interslope pattern. Thus, dormancy depth is positively and significantly correlated with seedling revival after drought. These results display that the microhabitat environment is the dominant adaptive factor in the natural selection for seeds dormancy as well as seedlings drought tolerance of wild barley, and it overrides any interslope migration and parallels regional patterns across Israel.

**P 5.97 - Genetic basis of drought resistance at reproductive stage in rice: separation of drought tolerance from drought avoidance**

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Drought tolerance (DT) and drought avoidance (DA) are two major mechanisms in drought resistance of higher plants. In this study, the genetic bases of DT and DA at reproductive stage in rice were analyzed using a recombinant inbred line population from a cross between a lowland indica and tropical japonica upland cultivar. The plants were grown individually in PVC pipes and two cycles of drought stress were applied to individual plants with unstressed plants as the control. A total of 21 traits measuring fitness, yield and the root system were investigated. Little correlation was detected of relative yield traits with potential yield, plant size and root traits, suggesting that DT and DA were well separated in the experiment. A genetic linkage map consisting of 245 SSR markers was constructed for mapping QTLs for these traits. A total of 30 QTLs were resolved for seven traits of relative performance of fitness and yield, 36 QTLs for five root traits under control, and 38 for 7 root traits under drought stress conditions, suggesting the complexity of the genetic bases of both DT and DA. Only a small portion of QTLs for fitness and yield related traits overlapped with QTLs for root traits, in which most of the positive alleles for fitness and yield related traits and root traits were from different parents, indicating that DT and DA had distinct genetic bases.

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P 5.98 - Differences in flag leaf water use efficiency of adapted winter wheat cultivars to water stress

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The aim of this study was to determine water use efficiency (WUE) of selected winter wheat cultivars by two methods. Plants were grown in pots in greenhouse with full or a half irrigation dose from the start of the stem elongation. Fully expanded, intact flag leaves were measured in a closed leaf chamber connected to CO₂ and H₂O analysers. Assimilation (A) and transpiration rates (T) at steady state under constant conditions of radiation, humidity, temperature, CO₂ and air flow were measured. The WUE was calculated as A/T. It was possible, according to WUE of adapted and non adapted flag leaves to divide the tested cultivars to four groups: the cultivars in the first group (e.g. Ilona, Estica) were saving water at the stressed and well watered conditions, cultivars of the second group (e.g. Ebi, Samanta) were saving water only at stress conditions, the third group of cultivars (e.g. Astella, Zdar) spent water at both conditions. Cultivars Contra and Clever belonging to the fourth group spent water even at water shortage. The second method based on carbon isotopic ratio (¹³C/¹²C) has been used to estimate WUE integrated over the life-time of the leaf. Highly significant correlation between the difference of ¹³C discrimination at well watered and stressed conditions and the absolute value of ¹³C discrimination at stressed conditions was found. The highest differences between treatments (up to 3.5‰) were estimated in the cultivars Ebi and Samanta with lowest carbon isotope ratio (close to -25.8‰) in water stressed leaves.

P 5.99 - Response of barley plants to water stress

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This research has been focused on the changes in adaptability of three varieties of barley after treatment of long-acting water stress and nitrogen supply. The objectives of this research were to compare osmotic potential, stomatal conductivity and gas exchange, additionally from transpiration rate and photosynthesis rate calculated water use efficiency (WUE) in the fifth leaf in well-watered and drought-treated plants under normal and low nitrogen supply. The dry matter distribution was determined simultaneously. Three varieties of barley - ‘Norimberk’, ‘Amulet’, and ‘Krone’ has been grown in the pots with 10 litres of soil under the shelter with controlled watering treatments (well-watered down to -20kPa and water stressed down to -40kPa, measured by tensiometers). N-fertilizing 85 mg N per pot and 425 mg N per pot in NH₄NO₃. Osmotic potential of the squeezed sap from leaves was measured by hygrometer/psychrometer, photosynthesis, transpiration and stomatal conductivity by gazometric system on intact leaves. The old variety ‘Norimberk’ indicated an ability of adaptation to water stress by lowering osmotic potential under the normal supply of nitrogen, but not at low nitrogen supply. The osmotic potential of ‘Amulet’ and ‘Krone’ remained with minor changes in the same conditions. ‘Amulet’ and ‘Norimberk’ increased WUE under the drought conditions at normal supply of nitrogen, unlike ‘Krone’. Stomatal conductivity decreased in all varieties under the water stress. The most lowering of dry accumulation was found in ‘Norimberk’. In comparison, there were found different strategies in adaptation among old and new varieties of barley to water and nitrogen supply.
P 5.100 - Studying and genetic improving water use efficiency of wheat in China

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In most winter wheat areas of northwest China, the annual precipitation has ranged about 500 mm, but wheat yield has increased gradually from 750 kg/ha before 1950 to more than 3750 kg/ha presently. In China, So wheat WUE measured by means of grain yield (kg)/annual precipitation (mm) in rainfed land has increased from 0.1 kg/mm before the 1950s to 0.5 kg/mm or even 1 kg/mm in small area by now. The flag leaf WUE of diploids and tetraploids, increased as the wild species become domesticated species. The flag leaf WUE and single plant WUE and field WUE increased as the chromosome ploidy levels increased (2x 4x 6x) in wheat evolution, among modern cultivars, these WUE of varieties for irrigated land are higher than for those for dryland. The order of flag leaf WUE of different chromosome genomes is AA>BB>DD>RR. Among twenty Chinese spring diplosomic lines, the flag leaf WUE of A ditelosomic group is the highest, and high WUE genes were located on 1AL, 2AS and 7AS chromosome arms. Among seven wheat-rye addition lines, the high WUE genes located on 4R chromosome, and the flag leaf WUE of 5R addition lines is the lowest. Two QTLs controlling leaf WUE (LWUE) are detected on chromosome 1A and 6D, which explains 11.48% and 14.84% of variation of LWUE, respectively. Ten QTLs significantly affect per plant WUE (Dry weight of biological yield/ amount of water used per plant, PWUE), and of them two QTLs are located on A genome (4A, 7A), four on B genome (3B, 5B) and four on D genome (3D, 6D). Six QTL significantly control leaves and stems WUE (Dry weight of stem and leaves/ amount of water used per plant, LSWUE), of them two are on A genome (2A, 4A), three on B genome (3B) and one on chromosome 6D. Two pairs of interacting QTL affecting LSWUE are identified on chromosome 1A-1D and 4A-5A. Five QTLs significantly control root WUE (Dry weight of roots / amount of water used per plant, RWUR) and of these, three are on A genome (2A, 3A, 4A), and two QTLs on B genome (2B, 5B). Three pairs of interacting QTLs influencing RWUE are identified on 3A-3D, 3A-6A and 7A-7B. Most of the QTLs controlling different WUE are detected on A genome.

P 5.101 - Ion distribution in seedlings of Aloe vera and Salicornia europaea in response to NaCl stress and their salt tolerance

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Research was conducted on xerophyte Aloe vera, a traditional medicinal plant, and Salicornia europaea, a typical halophyte to investigate the effects of NaCl treatments on plant dry substance accumulation rate, water content of shoot, ion distribution in different organs and cells. The seedlings were treated with 100~200 mmol-L-1 NaCl. After 10 d, the dry substance accumulation rate, water content of dry weight basis, Na+, Cl-, K+ contents of root and shoot, Na+, Cl-, K+ and Ca2+ relative contents in total inorganic ions of different tissues by X-ray microanalysis were determined. Result showed that the growth of xerophyte A. vera was significantly inhibited by NaCl stresses and the more NaCl concentration, the more growth inhibition of A. vera seedling. However, the growth of halophyte S. europaea dramatically promoted in response to NaCl stresses. S. europaea seedlings had good regulating K+ homeostasis in roots and very high root-to-shoot Na+, Cl- fluxes, whereas A. vera seedlings were provided with excellent function to salt exclusion and selective K+ absorption and transport. It is very meaningful that Na+, Cl- in aqueous tissue accumulated sharply by NaCl stress, this phenomenon was first reported by us, suggesting that salt accumulation in leaf aqueous tissue of A. vera play an important role in alleviating salt-ion toxicity and osmotic stress. Compared with A. vera seedling, S. europaea seedling whose growth requires salt maintained considerably higher Na+, Cl- peak and Na+, Cl- relative percentage in total inorganic ions, especially in its assimilating shoot both under control and NaCl treatment. Percentage of sum of Na+, Cl- content in total inorganic ions of assimilating cells in S. europaea shoot was as high as 75.6%, while that of aqueous cells was only 44.67%, So aqueous tissue was not provided with “salt accumulation” function.
P 6.01 - Modulation of intrachromosomal homologous recombination and stress-induced DNA rearrangements by the Arabidopsis RecQl4A gene

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RecQ proteins in bacteria, yeasts and animals play crucial roles in DNA recombination/repair, replication and genome stability maintenance. Arabidopsis contains seven RecQ-like genes. Here, we report on functional analysis of the Arabidopsis recQl4A gene. Analysis of three Arabidopsis recQl4A mutant alleles revealed no obvious developmental defects or telomere deregulation in plants grown under standard growth conditions. However, the mutant seedlings were found to be hypersensitive to UV light and MMS but more resistant to mitomycin C (MMC), as compared to wild type plants. The average frequency of intrachromosomal HR in the mutant was increased 7.5- to 19-fold in the absence of genotoxic stress and over 200-fold after MMC treatment, as compared to wild type grown under standard conditions. These data reveal roles for Arabidopsis RecQl4A in modulation of HR mediated DNA repair and suggest novel means for improving gene targeting in plants. Furthermore, we employed the recQl4A mutant to study the effects of various environmental cues on the induction of ICR in plants. The results showed that NaCl and reactive oxygen species increased, but ABA and mannitol decreased the ICR frequency in both wild type and recQl4A mutant plants with similar ratios. Thermal stress, cadmium and salicylic acid analogues induced ICR frequency in the wild type but not in the recQl4A mutant. No induction of ICR was observed in wild type or mutant plants exposed to ethylene, or methyl jasmonate. The data suggest that in plants exposed to environmental stimuli, RecQl4A dependent and – independent pathways of ICR induction are activated.

P 6.02 - Patterns of gene expression in peach bark and leaves in response to water deficit and cold treatment

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Previous studies have revealed considerable overlap in the identity of genes that respond to different abiotic stresses. However, many of these genes have been conserved across plant taxa, ranging from herbaceous monocots to woody dicots. Information regarding the expression of these genes in response to different stresses within a plant is scarce, particularly for woody plant species. We have identified a number of genes from peach (Prunus persica L. [Batsch.]) known from previous studies in herbaceous plants to be associated with response to cold treatment or dehydration. Examination of the expression patterns of these genes in peach bark or leaves with respect to cold treatment or water deficit stress was undertaken. Some of the genes associated with abiotic stress in herbaceous plants appear to be up-regulated in response to cold, but down-regulated in response to water deficit stress. These include a peach pollen coat protein-like gene similar to Kri1 and a novel peach dehydrin gene (PpHn3). Similarly, a peach ERD3-like gene which was down-regulated by cold treatment was also down-regulated in response to dehydrative stress. A recently isolated peach dehydrin gene, PpHn2, was not found in either of two subtracted libraries from cold treated trees, but showed a strong response to dehydrative stress. In this context the supposed overlap in dehydrin gene expression in response to cold and water deficit treatment does not represent the same gene responding to both stresses, but rather different family members with specific and presumably independent responses to these two stresses.
Our work presents a functional genomics approach to dissect drought signal transduction in cereals by using *A. thaliana* as a model system. We have analysed four clones, named 6H8, 6g2, 1C1 and 10d10, previously isolated in durum wheat in response to drought using a suppression subtractive library. They showed sequence similarity with genes in *A. thaliana* never reported to be involved in stress response: a putative transmembrane protein belonging to the UPF0016 family, a RING-FINGER protein, a farnesylated protein and an E2-ligase involved in sumoylation pathway. To identify the function of these genes two approaches are currently in progress: 1) analysis of the knock-out T-DNA mutants via a reverse-genetics approach, and 2) protein-protein interaction analysis using yeast two-hybrid system. The isolated T-DNA mutants were studied under greenhouse and laboratory conditions to test both their phenotype and stress resistance. The knock-out mutants showed a particular phenotype in control condition (20 °C, 8 h light, 150 μE) with red leaves and trichomes. In the literature it is reported that the same phenotype was shown by the wild-type in high light conditions, revealing that the red pigmentation, due to anthocyanins, is caused by ROS accumulation. To test the level of stress-tolerance of these mutants we measured chlorophyll fluorescence (Fv/Fm) in response to photo-inhibition (1 h at 2000 μE and 10 °C). The mutants showed a lower Fv/Fm than the wild-type plant, suggesting a higher sensitivity to light stress. We have also found that the mutants flower later than the wild-type plants only in short day condition. The future aim is the characterisation of the mutant plants in drought and cold stress conditions to understand the particular phenotype and the resistance. The 6g2 and 10d10 genes are putatively involved in sumoylation pathway and a protein-protein interaction study via yeast two-hybrid system has begun.
Plantlets of *Populus euphratica* (from Ein Avdat natural park, Israel) were obtained by in vitro culture, ex vitro acclimated, transferred and acclimated to Nancy's greenhouse conditions. They were transplanted into 7.5 L-pot filled with peat-sand mix (50/50 V/V). A moderate, increasing drought stress was applied and controlled for 6 weeks through soil volumetric water content (SWC). A predetermined batch of plantlets (including control and stressed trees) was harvested at 4 stress intensities (10, 7.5, 5, 4% SWC) and after 10 days back to fully available water, in order to analyse transcriptome in leaves and roots, and proteome and other biochemical compounds in leaves (pigments, soluble carbohydrates). Growth (height, diameter, root elongation), water potential, leaf relative water content, net CO$_2$ assimilation rate and stomatal conductance were measured on another batch of plants following the same drought time course and recovery. The degree of sensitivity to drought of the measured physiological parameters was established. The most sensitive to the less sensitive were stem diameter growth, height diameter, stomatal conductance, leaf relative water content, mid-day leaf water potential, photosynthesis, root elongation and predawn leaf water potential. An EST database with the *P. euphratica* ESTs including annotative attributes can be viewed at http://sputnik.btk.fi. In common with other *P. euphratica* microarray experiments, very few genes (68 in leaves and 39 in roots of the 7400 present on the array) were regulated by drought. In leaves, the number of regulated genes which increased with stress intensity returned to almost zero after re-irrigation. By contrast, the number of proteins in which abundance was modified decreased with stress intensity and remained important after re-irrigation. Moreover, while the fold change of most up-regulated genes increased with stress intensity, the relative abundance of most proteins was diminished with increasing stress intensity. Nature of regulated genes, at the level of the transcript or of the protein, are analysed and discussed in relation to ecophysiological responses.
Drought is considered as a major constraint to rainfed rice production. Progress in genetic improvement of rice for drought tolerance is limited. Identifying quantitative trait loci (QTLs) linked to drought resistance traits will help to develop high yielding rice cultivars suitable for water limiting environments through marker aided selection (MAS). QTLs associated with drought resistance traits were mapped by field testing recombinant inbred lines developed from IR20 x Nootripathu, two indica ecotypes adapted to target population of environments. Significant variation was found among the rice lines for the various physio-morphological traits under water stress in two locations. A total of 1,125 primers were used and 56 markers were assigned to eleven rice chromosomes covering a total map length of 652 cM. In total, 54 QTLs for 11 different traits were identified, which individually explained 2.1 to 30.5% of the phenotypic variation. The region RM212-RM302 on chromosome 1 was linked to plant production traits under drought stress. Similarly, the marker RM 263 on chromosome 2 is also associated with drought resistance traits. Markers consistent across environments and genetic backgrounds were identified for various drought resistance and plant production traits under water stress and may be useful in MAS for rainfed rice improvement.

A large program, supported by the French national plant genomic network, Génoplante has been established to reveal the function of orphan genes. Wheat and maize EST sequences have been blasted and then aligned against the \textit{A. thaliana} genome to obtain orthologous genes of unknown function in this model species. In silico datamining allowed a selection of a subset of these genes which are expressed under drought, saline (NaCl) or osmotic (mannitol) stresses. Finally mutants in these genes have been sought in the INRA Versailles insertional mutants collection. 467 mutant lines have been screened for a drought response phenotype using a protocol set up in our group. As we are writing this abstract, 206 lines have been screened. Among them 54 have been retained using a test comparing rosette surfaces between mutant lines and a control line after five days of reduced watering. These lines are then validated in a second more stringent screen in which water potential is controlled at 60, 40 and 20% of normal water potential. The drought response is then evaluated. In addition, a recovery test is also performed by stopping watering for a few days and then rescuing plants by rewatering. The overall strategy and procedure will be discussed.
P 6.07 - Ectopic overexpression of novel soybean stress-responsive transcription factor GmDREB gene in wheat enhance drought tolerance during seedling development

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The transcription factors DREB/CBF specifically interact with the dehydration- responsive element/C repeat (DRE/CRT) cis-acting element and control the expression of many stress-inducible downstream genes in Arabidopsis. By screening of drought-induced soybean cDNA library, we isolated four cDNA for DREB homologs: GmDREB1, GmDREB2, GmDREB3 and GmDREB4. The expression of GmDREB2 was induced by drought, high-salt (200 mmol/L NaCl), low temperature (4 °C) and ABA (200 μmol/L); the GmDREB3 was induced by low temperature and was negative controlled by drought; and the GmDREB4 was induced by high-salt only. Gel mobility shift assay showed that these four genes specifically bound to DRE/CRT element in vitro. In yeast one-hybrid assay, these four genes specifically activated genes fused with the promoter containing three randomly repeated copies of the wild-type DRE/CRT sequence. Two vectors containing GmDREB1 gene under control of CaMV 35S promoter and stress-inducible Rd29A promoter were transferred into wheat via biolistic. Overexpression of GmDREB1 in transgenic wheat enhances drought tolerance in comparison with checks during seedling development under greenhouse conditions. We also analyzed the phenotype alterations of GmDREB1 transgenic wheat and found that overexpression of GmDREB1 gene in wheat had no negative effect on plant development. It was proved that novel GmDREB genes are potentially useful for producing transgenic monocots that are tolerant to drought.

P 6.08 - Gene expression of glutathione reductase in leaves of cowpea (Vigna unguiculata L. Walp) and total soluble enzymatic activity under progressive drought stress, desiccation and ABA treatment

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Two cDNAs encoding respectively a dual-targeted isoform to both mitochondria and chloroplasts (GR1) and a cytosolic isoform (GR2) of the enzyme glutathione reductase (GR) were cloned and sequenced from leaves of Cowpea (Vigna unguiculata L. Walp). The experiments were conducted on two cultivars, one tolerant to drought (V. u. cv. EPACE-1), the other susceptible (V. u. cv. 1183). RT-PCR analysis on GR isoform gene expression and GR specific enzymatic activity were determined under a progressive drought stress, desiccation and ABA treatments. RT-PCR studies showed that the expression level of the cytosolic isoform was higher than that of the dual-targeted in all treatments. Leaf GR enzymatic activity was enhanced under drought stress for cv. 1183 only and after a 24h-ABA-treatment for both cultivars. Regarding the desiccation treatment, only small variations were detected. In response to drought, the highest transcript level for the cytosolic isoform corresponded to the lowest leaf water potential (-2.0 MPa) and this was true for both cultivars. Regarding the expression level of the dual-targeted isoform, it remained very low regardless the leaf water potential value. Desiccation treatment led to small variations in the transcript level for both isoforms and for both cultivars. In accordance to the GR enzymatic activity results, ABA also stimulated GR gene expression (cytosolic and dual-targeted) after a 24h treatment, hence suggesting an ABA-induced generation of active oxygen species (AOS). Taken together, these results show a noticeable activation of the antioxidant metabolism under a progressive water stress, which appears to be rather limited under a fast desiccation.
P 609 - Microarray analysis for transcriptional profiling of potato cells under abrupt or gradual-adaptive exposure to water stress

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To distinguish transcriptome changes as generalized response to water stress from those involved in adaptation/tolerance, potato cells were abruptly exposed or gradually acclimated to grow at low water potential created by the addition of increasing concentrations of polyethylene glycol (PEG) to the nutrient medium. Physiological and biochemical analysis has revealed that gradual acclimation allows active growth by means of a set of metabolic changes, including proline accumulation, de novo protein synthesis, changes in membrane lipid composition, not observed in PEG-shocked cells (Leone et al. 1994, Plant Physiol, 106: 703-712; Leone et al. 1996, Plant, Cell & Environ 19: 1103-1109). TIGR 10K potato cDNA slides (www.tigr.org) were hybrized, at least in six replicates, including dye swap, with labeled Cy3-dUTP and Cy5-dUTP retro-transcribed total RNA from control vs PEG-shocked cells or control vs PEG-adapted cells. Although up-regulated genes (>2.0-fold increase) belonging to different functional categories (including transcription factors, stress-proteins, amino-acid, protein and carbohydrate metabolism, cell wall synthesis and others) were identified in both PEG-shocked and adapted potato cells, only 13 cDNAs were common to both treatments. Similarly, a limited number of common down-regulated genes were identified in the two cell populations. Altogether these data confirm that different gene networks are mediating the short- and long-term cellular response to water stress. The contribution of specific functional gene classes in the adaptation or in the abrupt response to water stress will be discussed on the basis of the microarray results as well as the differential expression validation by RT-PCR or Real-time RT-PCR.
P 6.10 - Understanding responses of seedlings to drought and its genetic basis in rice

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A 241 recombinant inbred lines derived from a cross of Zhenshan 97 × Minghui 63 were employed with an attempt to understand responses of rice to water stress induced by polyethylene glycol (20% in PEG6000, equivalently to -0.49MPa). Between well-watered and water-limited conditions, the two parents generally showed significant differences in plant height (PH), maximum root length (MRL), root fresh weight (RFW), number of roots (RN), shoot fresh weight (SFW), and root: shoot ratio (RS). Significant differences in all studied traits between the two water supply conditions were observed for both the two parents, suggesting that the PEG treatment erected its effects on two parents. The relative performances (described as ratio of phenotypic value under water stress to that of identical traits under well-watered condition) in lines arranged from 0.44 to 2.62 for RN, 0.39-1.13 for SFW, 0.49-1.17 for PH, 0.62-2.24 for MRL, 0.24-3.32 for RFW, 0.44-3.22 for RS, suggesting that lines showed different responses to the water stress condition. There were significant correlations for individual measured traits between well-watered and PEG-induced drought conditions. QTL analysis were carried out based on a mixed linear model using QTL Mapper with a threshold of both p < 0.001 and LOD = 2.7. Five and eight QTL were identified for PH in well-watered and drought conditions, respectively, six and three for SFW, three and eight for RN, six and six for MRL, three and four for RFW, three and six for RS. Several QTLs for identical trait under two conditions were observed to share the similar chromosomal regions, respectively. For example, RG424-RZ667 on chromosome 6 had effects on PH in both two water supply conditions, C112-RG236 on chromosome 1 and C734b-RG360-R3166 on chromosome 5 for SFW, R887-G1128a-C996 for MRL, C944-C746 on chromosome 3 and RG360-R3166 on chromosome 5 for RFW. Generally, QTLs for traits under drought condition were different from those under well-watered conditions, suggesting that different genes control plant growth under different water supply, respectively. Also, QTLs for relative performance of given trait were different from those detected in well-watered or water-limited conditions.
P 6.11 - A trehalose biosynthesis gene of plant origin used to increase drought tolerance in plants: genetic engineering of the model plant Nicotiana tabacum (tobacco) and crop plant Zea mays (maize)

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Trehalose plays an important role in abiotic stress protection. In this work, we aim to improve drought tolerance in tobacco and maize, by transformation with the Arabidopsis thaliana trehalose phosphate synthase gene (AtTPS1), involved in trehalose biosynthesis. The AtTPS1 gene under the control of the CaMV35S promoter was inserted in pGreen0229 vector and used for Agrobacterium-mediated transformation of tobacco. Primary transformants were analyzed by PCR. Thirty T₀ lines were obtained and seeds were germinated on selective media to obtain T₁ plants grown to set seeds (T₂). Three homozygous lines were selected and gene expression confirmed by northern and western blots. Assays were conducted to test the tolerance of transgenic plants to drought (water withdrawal). Transgenic lines showed better responses to stress situations than wild type plants. We could conclude that the TPS1 gene from Arabidopsis can be successfully used to increase abiotic stress tolerance in model plants and hence important crops. For maize transformation, we used maize line Pa91. Immature zygotic embryos were collected 20 days after pollination initiating embryogenic calli culture that were electroporated plasmid DNA. Electroporated calli were kept on selection media for eight weeks and embryos started to appear. Embryos were then regenerated to plants that were transferred to the greenhouse. Several putative transgenic lines were obtained and Southern blot analysis was performed. Plants had normal phenotypes although smaller than wild type but no aberrant phenotypes were detected in T₀ plants, with the exception of non-synchronized flowering and the formation of seeds with little endosperm.

P 6.12 - Identification and characterization of drought induced transcripts in peanut

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Drought stress is reported to alter gene expression. Some of the stress induced transcripts may be specific for either drought tolerance or drought susceptibility. To identify the drought-induced transcripts, peanut genotypes with varying drought tolerance characteristics were subjected to water stress. Peanut (K-1375) plants were grown in pot culture for 30 days and subjected to water stress for five to 15 days by withholding irrigation. Total RNA was isolated from leaves and Differential Display RT-PCR (DDRT-PCR) was performed using cDNA made from the total RNA. Two primer combinations (P1 and T3) were used for PCR. The PCR reaction consisted of 10ng of cDNA, 0.2μl dNTP (5mM), 1μl of each primer (1.5nm), 1μCi of αP32dATP and 3 units of Taq DNA polymerase. The PCR product was denatured using Formamide dye and incubating at 95 °C for 2 mins and run on a 6% urea sequencing gel. The gel was dried and exposed to X-ray film for 16-24 hrs. Sequencing gel showed presence of two differentially expressed products. These bands were eluted from the gel and re-amplified with the same primers used for DDRT-PCR. The PCR product was run on a 1.5% agarose gel and the two bands were found to correspond to approximately 150bp and 250bp. The PCR product was purified using the minielute kit (Qiagen) and then cloned to a TA cloning vector (Qiagen). The recombinant vector was transformed into DH 5 α and then plated onto X-Gal/ IPTG/ Amp plate. White colonies were sub-cultured and sequenced. The sequence was compared with NCBI database using the BlastX program. The results showed no similarity with the known sequences available in the NCBI database (Acc.no.AY960638). The amino acid sequence derived based on the nucleotide sequence indicated that it is rich in Lucien. Studies are in progress to determine differential expression of this transcript between drought-susceptible and drought-tolerant peanut genotypes at different water stress levels.

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Phytocystatins are reversible inhibitors of cysteine proteinases playing part in plant defence strategies against various pathogens. Recently, we have reported their involvement in drought-stress tolerance mechanisms in legume plants. RT-PCR analyses of cowpea cystatin expression in response to drought revealed the presence of at least two cystatin-like messengers, in leaf tissues. Screening of a cowpea leaf cDNA library led to the isolation of two cDNA clones 857 bp- and 929 bp-long, denoted VuC1 and VuC1-i respectively. Both correspond to proteins including two cystatin domains. These two clones are identical apart from a 91 bp insertion with intron feet both at the 5' - and 3' - ends in VuC1-i. This insert is located exactly where introns are found in other phytocystatin genes. Six cowpea cultivars were submitted to different levels of drought corresponding to leaf water potentials of -1.0 MPa (mild stress), -1.5 MPa (moderate stress) and -2.0 MPa (severe stress). Plants submitted to moderate stress were rehydrated for 24 h. RT-PCR analyses on leaf extracts showed the presence of the two cystatin-like messengers, corresponding to VuC1 and VuC1-i. In most cultivars, VuC1-i messengers were more abundant than VuC1 messengers in well-hydrated and rehydrated plants. However, amounts of VuC1-i messengers decreased in response to drought while that of VuC1 messengers increased. These results suggested that, under water deficit conditions, alternative splicing occurred in cowpea leaf tissues to adjust cystatin gene expression to increasing cellular need for protease inhibitor molecules.

P 6.14 - Fine mapping and candidate gene identification of QTLs for drought tolerance in rice

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During the past decades molecular tools have been widely used for isolating quantitative trait loci (QTL) and genes for drought tolerance in plants. But because of its genetic complexity, little is known about the genetic mechanism regulating gene expression under drought conditions. A new strategy was adopted in this study for fine-mapping several DT QTLs with large effect using overlap DT introgression lines (ILs). The ILs with the major DT QTL were used to identify functional candidate genes for drought tolerance in rice. The main objectives of this research are to narrow down the target DT QTL to a very small genomic region and try to identify the overlapped positional and functional candidate genes. Primary results showed that the strategy of fine mapping QTL using overlapping ILs is very effective and three QTLs were narrowed down to very small chromosome regions; bioinformatics search was processed for identifying DT positional candidate genes on the target regions, compared these data with functional candidate genes resulted from SSH analysis using ILs with major QTL, some overlapped candidate genes were identified and functionally classified for further confirmation.
P 6.15 - A guard cell-specific MYB transcription factor regulates stomatal activity and plant water loss

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The regulation of the opening of stomata allows the plant to cope with the conflicting needs of ensuring a sufficient uptake of CO₂ for photosynthesis and of minimizing water loss. Guard cells integrate internal signals and environmental stimuli to modulate stomatal aperture for plant survival under diverse conditions. Evidence suggests that modulation of transcription plays an important role in controlling guard cell activity, even though the details of this level of regulation remain mostly unknown. Here we report the characterization of AtMYB60, a R2-R3 MYB gene of Arabidopsis, as the first transcription factor involved in the regulation of stomatal movements. AtMYB60 is specifically expressed in guard cell and its expression is negatively modulated during drought. A null mutation in AtMYB60 results in the constitutive reduction of stomatal opening and in decreased wilting under water stress conditions. Transcript levels of a limited number of genes are altered in the mutant, many of which involved in the plant response to stress. Our data indicate that AtMYB60 is a transcriptional modulator of physiological responses in guard cells and open new possibilities to engineering stomatal responses to improve plant survival during drought.

P 6.16 - Molecular responses to drought stress: expression of TdDRF gene in several durum wheat varieties in controlled greenhouse and field conditions

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Molecular responses to drought stress: expression of TdDRF gene in several durum wheat varieties in controlled greenhouse and field conditions. Climate fluctuation and the relationships with quality and availability of water and temperature represent important factors affecting crop production, leading to substantial harvest variations from year to year in connection with the different stresses. The responses of plants to the abiotic stresses have been the focus of physiological studies for a long time, and more recently, of molecular and genetics studies and transgenic experimentations. Many genes and gene families have been individuated to be strictly related to drought, salt and cold stresses and have been analysed in different plant systems. They can be useful to individuate the genotypes that are involved in the mechanism of the resistance and tolerance and that could be useful for obtaining new varieties by transgenesis or by assisted breeding. Using wheat databases and TC sequences related to DREB2A gene of Arabidopsis, we designed specific primers that have been used to analyse the RNAs from several Italian durum wheat varieties, as Cresco, Cicco, Simeto, Gianni, Cannizzo, Colosseo and varieties coming from field selection as Yavaros79, Atil2000, Jupare, Karalis and Capeiti 8, in a time course experiment after induction of drought-stress in a controlled greenhouse. A comparable open field time course experiment of drought stress is in progress at Obregon Station, CIMMYT. We found an unknown gene, never reported before in wheat, that resulted to be highly homologous to a gene recently described in barley. Results, obtained from both time-course experiments of drought-stress, concern the presence, the genetic variability and the expression levels of this gene, characterized by alternative splicing.
P 6.17 - Genetic dissection towards development of drought tolerance in lowland rice

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For areas of forced and unforced situations of water stress, it would be desirable to have rice varieties endowed with virtues of drought tolerance and stable yield. Genetic dissection of drought tolerance through QTL mapping in a RIL population (derived from the cross IR 58821/IR 52561) located 12 QTLs regulating drought tolerant and yield traits under water stress in the field conditions that were closely linked with DNA markers. The DNA segment on chromosome # 7 flanked by two linked AFLP markers viz., PC75M7 and PC12M9 showed pleiotropism for leaf rolling, leaf drying and drought recovery. Similarly, three QTLs each for dry root weight and root - shoot ratio on chromosome # 2, 4 and 5 were identified. Two QTLs one each for root / shoot ratio and dry root weight on chromosome 2 were consistent across genetic backgrounds. Research is in progress to identify the microsatellite markers that likely to fall in the above regions to improve the efficiency of MAS. Evaluation of Bi-Parental Progenies showed that single cycle of intermating of segregants in F2 had only little effect on creation of variability. Association analysis pointed out that among BIPs if selection pressure is exerted on the positive side for days to 70% RWC, root/shoot ratio, biomass yield and harvest index and on negative side for leaf rolling and leaf drying, it will result in higher yield under stress by breaking of unfavorable linkages. The nature of gene action governing the inheritance of drought tolerant, yield and its component traits in hybrids was also reported.

P 6.18 - Production of transgenic potato plants overexpressing the Δ1-pyrroline-5-carboxylate synthetase increases proline production and confers osmotolerance

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In an attempt to increase salt tolerance in potato plant, we have produced transgenic lines expressing the P5CS (Δ1-pyrroline-5-carboxylate synthetase) cDNA from Arabidopsis thaliana using the Agrobacterium-mediated transformation. This enzyme is responsible for conversion of glutamate to Δ1-pyrroline-5-carboxylate that is reduced to Proline. This latter is known compatible osmolyte accumulated in plant cells in response to salt and drought stresses. It’s supposed to be an osmoprotectant involved in osmotic stress tolerance. The constitutive expression of the transgene was verified at the RNA and protein levels. However, the resulting transgenic potato plants showed an important increase in Proline production levels in the presence of salt compared to nontransgensics. These transgenic potato plants showed also an improved tolerance to salinity (up to 100 mM NaCl) when cultivated in the greenhouse. Indeed, under these conditions, the potato tuber yields and weight in such transgenic lines were much less altered compared to the nontransgensics.
P 6.19 - QTL mapping and marker assisted selection for drought tolerance in rice (Oryza sativa, L.)

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Drought is one of the serious constraints to rainfed rice production world over. Identifying genomic regions (QTLs) contributing in drought resistance will help to develop rice cultivars suitable for rainfed regions through marker-assisted breeding. However, fewer QTLs associated with yield and its components under drought stress have so far been mapped in rice, especially in target populations of environment (TPE). Thus in this study, a total of 36 QTLs were identified for various plant phenology and production traits under natural but severe drought stress in the field at TPE using 177 recombinant inbred (RI) lines of Bala x Azucena, which individually explained 4.8 to 16.7% of phenotyping variation. Composite interval mapping detected G144, RM 252, C43 and R543, respectively, on chromosomes 3, 4, 5 and 12 to be linked to grain yield under stress. QTLs for leaf rolling, leaf drying, canopy temperature and panicle length under stress co-located at certain of these regions. Further, QTLs for several root traits were also overlapped with QTLs for grain yield under stress in these RI lines, thus confirming our previous findings that root trait QTLs had pleiotropic effect on yield under stress. Results showed that introgression of root trait QTLs would impact grain yield under drought stress in rice. However, this has to be validated using near isogenic lines (NILs) for root trait QTLs. Thus, we are developing IR20 NILs by introgressing QTLs associated with root traits from CT9993-5-10-1-M, a japonica accession with deep and thick root system. The progress in these directions is discussed.

P 6.20 - Zmcoi6.1 and its Arabidopsis thaliana ortholog, Atcoi6.1 are novel stress regulated genes

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Using PCR-cDNA Subtraction technique, we obtained Zmcoi6.1, a gene whose transcript strongly increases by abiotic stresses such as drought, cold and salinity. Stress signaling molecules such as abscisic acid, jasmonic acid and salicylic acid, also causes strong induction of the Zmcoi6.1 transcript as well as by membrane rigidification. Analysis of Zmcoi6.1 promoter sequence revealed several conserved cis-acting elements known as important in transcriptional regulation upon abiotic/biotic stress indicating that Zmcoi6.1 may be involved in general stress response. The Zmcoi6.1 gene sequence contains two introns and three exons. Detail analysis of Zmcoi6.1 transcripts reveals the presence of two different transcriptional forms where the larger one contains the first intron but not the second, while in the smaller no intron is present. Furthermore, sequence analysis of the putative ZmCOI6.1 protein identified one homolog in maize and several orthologs in rice and Arabidopsis. To investigate the possible involvement of this related genes in stress response we analyzed an Arabidopsis T-DNA insertion mutant in Atcoi6.1 gene, an ortholog of Zmcoi6.1. This mutant shows an increase in resistance to drought, cold and salt stress when compared to wild type Arabidopsis plants. Transcriptional activation studies of known stress regulated genes such as RD29a, CBP1, CBP2, RD22 and CBL, indicate that Atcoi6.1 acts independent of the main stress responses pathways in Arabidopsis. Our findings show the identification of a novel gene in maize that is a putative negative regulator in different abiotic stresses such as cold, drought and salinity. Furthermore, one of its orthologs shows similar function in Arabidopsis. ZmCOI6.1 regulation suggests it is a novel component in maize stress signalling.
Expression analysis of barley genes in response to drought stress during the reproductive growth stage using microarray

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Drought tolerance is a key trait for increasing and stabilizing barley productivity in dry areas. The understanding of the molecular mechanism of drought tolerance during the reproductive stages may facilitate the identification of novel genes controlling traits associated with drought tolerance for biotechnology-assisted genetic improvement of barley. In this study, the 22K Affymetrix GeneChip Barley 1 array was used to monitor changes in the transcription levels under drought stress of two cultivars, Tadmor and WI2291, drought tolerant and sensitive, respectively. The preliminary results revealed that 77 genes showed significant differences in transcript abundance in both varieties under drought stress. The list includes many drought-responsive genes that were identified in previous studies. The genes showing similarity to proteins of known function were classified into 14 different functional categories. These 77 genes were expressed in both varieties when plants were exposed to water stress; therefore, they are likely to be genes responsive to drought stress and not important in drought tolerance. When gene expression under drought stress was further analyzed, 372 genes were identified to be significantly differentially expressed between two varieties. Those genes with known function were classified into 15 different functional categories in biological process. Some of these genes are known genes related to drought tolerance, while the others are unknown function or novel genes, which may be involved in drought tolerance. These results could provide new insights to elucidate the mechanism for drought tolerance in barley during the heading stage.
Water is a major determinant of yield for farming wheat in the Mediterranean basin. Durum wheat is one of the most widely cultivated crops mainly grown under rain fed conditions often characterized by low rainfall and other stresses. Whilst classical plant breeding has successfully introduced new varieties, it suffers from the possibility of losing valuable alleles. Molecular genetics offers the breeders and scientific community new tools to identify genomic regions and candidate processes for the study, selection and tracking of factors defining responses to drought. We describe a new EUFVI-INCO-CT-2004-509136 project that combines quantitative genetics, crop physiology and transcriptome analysis to identify loci controlling wheat responses and growth under drought. A mapping population of durum wheat from two breeding lines, Lahn x Cham1 developed at ICARDA, is under study. Cham1 is adapted to Mediterranean dry areas (300-450 mm) whilst Lahn1 is tailored to more favourable environments (400-700 mm). 112 RILs are under study in three different ecosystems in Syria, Tunisia and Italy and a search will be made for quantitative trait loci (QTL). Individuals showing stability of yield under drought will be selected for transcriptome studies using the Affymetrix wheat chips. Accessions from ICARDA and CIMMYT are also under field study for selection of best germplasm for breeding and for marker assisted selection. The project also explores new opportunities to improve the socioeconomic problems related to the adoption of improved varieties. The philosophy used in the project is to integrate our knowledge of biochemical pathways, crop physiology, genetics and post-genomic tools for deconstructing the genetic elements of water use in wheat.
Overexpression of a novel transcription factor gene significantly improved drought and salinity tolerance in rice

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Transcription factors play key roles in controlling gene expression in many signaling pathways or biological processes. Understanding how transcription factors respond to abiotic stresses in plants will help to uncover the molecular basis of stress signal transduction and provide new opportunities in improving stress tolerance in economically important crops. In this study, a putative transcription factor gene was isolated from an upland rice IRAT109. The transcript of this gene was induced by various stresses including drought, salt loading, cold and ABA treatment. Functional analyses suggested that this gene encoded a nuclear-localized protein. The protein showed transactivation activity in yeast cell and the amino acids from 243 to 273 is indispensable for this activity. When this gene was overexpressed in rice cultivar Nipponbare under the control of CaMV 35S promoter, all transgenic plants showed normal phenotype and yield potential as the wild type plant. However, transgenic plants showed significantly improved drought resistance (indicated by 30% higher of spikelet fertility than control) when drought was applied at anthesis stage in two different field conditions. At seedling stage, more than 80% of transgenic plants were survived when control plants had completely died after drought or salinity stresses. These data suggested that this transcription factor might be very useful in improving drought or salinity tolerance in rice. The molecular and physiological mechanisms of this gene in improving stress tolerance are under further investigation.

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Genetic regulation of PEG induced carbohydrate accumulation in hydroponically raised wheat seedlings

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The mobilization of carbohydrates are considered very important during water stress. For the physical assignment of the gene(s) regulating stress-induced sugar accumulation, Chinese Spring (CS) 5AL and 5DL deletion lines were studied. The seedlings were raised in hydroponics and the effect of PEG induced water stress was evaluated in a time course experiment. Total water soluble carbohydrate (WSC), glucose, fructose, sucrose, fructan and glucan were measured. The genes affecting stress induced carbohydrate accumulation were assigned to the same chromosomal bins which contain the vernalization genes: Vrn-A1 and Vrn-D1, respectively both on the long arms of chromosomes 5A and 5D. This work presents the physical location of genes regulating stress induced carbohydrate accumulation during mild osmotic stresses. The sugar accumulation as a phenotype is independently expressed from the Fr genes and shown to be controlled by Vrn genes behaving in an epistatic manner. From this aspect, Vrn-A1 turned to be more effective than Vrn-D1: contrary to the 5A deletion lines, the 5D lines lost their capability to accumulate sugar content. This suggests that they have lost an important regulatory allele which is responsible for the sugar accumulation during water deprivation.
Depending on the mechanisms involved in drought resistance, plant functions can be modified durably even after return to more favourable conditions. Adaptive mechanisms (photosynthesis and leaf water status regulation) suggest the involvement of different adaptation strategies depending on the genotype in sunflower. The aim of this research work is to identify the genomic regions involved in various physiological abilities of adaptation to drought by the analysis of a population of recombinant inbred lines and their parents. The experiment was conducted in a greenhouse using a randomized complete block design with three replications under well-watered and water-stressed conditions. Quantitative trait loci (QTL) analysis was carried out with 76 recombinant inbred lines (RILs) of sunflower derived from a cross between ‘PAC-2’ and ‘RHA-266’, to identify the genomic regions responsible for the expression of drought tolerance of several physiological traits. Genetic control of physiological traits related to photosynthesis (chlorophyll concentration, net photosynthesis and internal CO₂ concentration) and water status (stomatal conductance, transpiration, leaf water potential and relative water content) was evaluated in well-watered and water-stressed conditions. Genetic variability was observed among RILs for all the traits studied. The comparison between the best RIL and the best parent considered as Genetic Gain or transgressive variation, showed a significant difference for most of traits studied in both well-watered and water-stressed conditions. Genetic Gain was also observed when the best parent was compared with the mean of 10% of selected RILs. Using an AFLP and SSR linkage map, several QTLs associated with the studied traits were identified and the effects of each QTL are moderate. The putative target regions for drought tolerance improvement are discussed and the information obtained should aid in the identification of key physiological traits that confer drought tolerance.
P 6.26 - Identification of drought resistance candidate genes in wild emmer wheat (Triticum dicoccoides) and wild barley (Hordeum spontaneum) from Israel using cDNA-AFLP analysis

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The main objective of this research is to identify genes that are associated with drought resistance within the gene pool of the wild progenitors of wheat (Triticum dicoccoides) and barley (Hordeum spontaneum). Wild wheat and barley originating from drought-prone ecoregions carry unique genes and alleles underlying drought resistance traits. We compared the expression patterns of drought resistant genotypes vs. drought sensitive genotypes, under severe drought stress at the seedling stage, by cDNA-AFLP analysis. Expression profiling by cDNA-AFLP combines AFLP and RNA-fingerprinting, commonly used to display or compare the transcriptome of a specific tissue, treatment or developmental stage. A large set of transcript-derived fragments (TDFs) was amplified from wild barley under drought stress. Eleven TDFs showing differences between drought resistant and drought sensitive genotypes were isolated, sequenced and selected for further analysis based on their sequence homology with ESTs derived from drought- or salt-stressed Triticea EST libraries. Expression patterns of five potential TDFs displayed coincidence between cDNA-AFLP and RT-PCR in sensitive vs. resistant wild barley genotypes under control and dehydration stress. The same approach is used to compare the expression patterns of resistant and sensitive wild wheat genotypes. Furthermore, TDFs identified in wild barley are also being tested now in wild wheat as potential novel drought resistance genes. We show here that comparisons of expression patterns of drought resistant vs. drought sensitive wild barley and wild wheat genotypes, subjected to severe dehydration stress, enabled us to identify novel drought resistance candidate genes.

P 6.27 - Cloning of drought-tolerance related genes rNCED, Dr1 and Dr2 from rice cv. Zhonghan 3 through DDRT-PCR and RT-PCR approach

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Limited water resource available for crop production is becoming an increasingly concerned problem worldwide. In China, drought happens frequently and about 25% of the arable land is affected by water drought damage. Even in the main rice-growing region in Southern China, rice suffers seasonal water deficit resulting in heavy yield losses. In recent years, many stress-inducible genes like LEA, DREB, RD29 that have the potential ability to improve the drought tolerance of crops such as maize, wheat, rice and some vegetables have been cloned from several plants (Yamguchi-Shinozaki 1993; Wakui 2002; Dubouzet et al. 2003). Genetic transformation has been used as an approach to address water deficit problems (Park et. al. 2005 a, b; Liu et al. 2005). ABA is involved in adaptation of plants to various stresses and NCED gene plays key role in ABA synthesis under water stress in Arabidopsis, cowpea, maize and tomato. Yet NCED and other drought tolerance related genes and their function in rice remain to be studied thoroughly. In this study, a primary effort was made to clone drought-induced rNCED and two other functionally unknown genes Dr1, Dr2 from upland rice cv. Zhonghan 3 through mRNA DDRT-PCR and RACE technique. Nucleotide blast research revealed that the cloned rNCED gene shared 74% sequence identities with vp14 and NCED genes from corn and tomato. Dr1 and Dr2 shared 99% identities with putative drought tolerance related genes from Arabidopsis registered in NCBI. The molecular analysis, expression profiles and functions on drought tolerance are under quick investigation.
P 6.28 - Analysis of role of Hv-WRKY38, a transcription factor involved in cold- and drought response

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The WRKY gene family represents one of the major groups of plant-specific transcriptional regulators implicated in many different processes. This class of transcription factors is defined by an amino acid sequence with DNA-binding activity known as WRKY domain. Hv-WRKY38 is a new gene coding for a WRKY protein in barley, whose expression is involved in low temperature and drought stress response. Hv-WRKY38 is early and transiently expressed during exposure to low non-freezing temperature, in ABA-independent manner. Furthermore, it shows a continuous induction during dehydration and freezing treatments. Sub-cellular localization experiments showed the Hv-WRKY38 protein accumulation into the nucleus of epidermal onion cells. Moreover, bacterially expressed Hv-WRKY38 is able to bind in vitro to the W-box element (T)TGAC(C/T) also recognisable by other WRKY proteins. Hv-WRKY38 genomic sequence was sequenced and mapped onto the centromeric region of the barley chromosome 6H. Arabidopsis and rice sequences homologous to Hv-WRKY38 were also identified. To establish the role of Hv-WRKY38 in the regulation of gene expression during stress response, we developed useful genetic backgrounds for functional studies. In particular, ectopic over-expression was carried out in both monocot (wheat) and dicot (Arabidopsis) plants with an in planta high constitutive expression system. First evidences of phenotype analysis showed an earlier flowering time in CaMV35S:Hv-WRKY38: NOS transformants Arabidopsis vs wild type. Further investigations of transgenic plants phenotype in water-limited conditions are currently in progress.

P 6.29 - Drought modulated transcriptome in maize developing kernels

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In order to analyze gene expression in response to water stress, transcription profiling by DNA array technology was carried out on developing maize kernels. A targeted microarray strategy has been devised, selecting from public data bases 1000 tentative contigs (TC) coding for products involved, or hypothesized to be involved, in stress response and in starch synthesis and grain filling, beside two hundred TC expressed in developing kernels of unknown function. From these selected 1000 TC, specific 50-mers were designed and spotted in duplicate onto glass slides (MWG custom service). Using these oligo DNA arrays we compared transcripts from 10DAP kernels of two highly susceptible and two drought tolerant Recombinant Inbred lines, grown under well watered field conditions or under water stress. We found that 106 genes were significantly regulated by drought in at least one of the genotypes, and that they differ considerably in their response to water deficit. The genes differentially expressed under the two water regimes were localized on a genetic map, on which QTLs related to drought tolerance had been previously detected by linkage analysis.
P 6.30 - DDRT-PCR analysis of differentially cDNAs expression in chickpea seedlings upon induction of drought stress

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Differentially display reverse transcriptase PCR (DDRT-PCR) was used to identify differentially expressed cDNAs in chickpea seedlings upon induction of drought stress. The sequence of differentially expressed cDNAs; 219, H1, 192, 214, and H3 showed similarities at the protein level to known drought inducible genes as protease inhibitor, cor-regulated gene, alanine aminotransferase, βAKIN1 from the SnRK1 complex and partB like nuclease containing domain protein, respectively. Semi-quantitative multiplex PCR was used to verify that that differentially amplified cDNAs were derived from differentially expressed genes. It appeared that the sequences 219, H1 and H3 were induced by drought stress.

P 6.31 - Osmotic adjustment in transgenic citrus rootstock Carrizo citrange (Citrus sinensis Osb. X Poncirus trifoliata (L.) Raf.) overproducing proline

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Citrus being a perennial tree with a long productive period is exposed to frequent soil and atmospheric drought. In the major citrus growing regions in Brazil, despite the adequate amount of annual rainfall, yield losses up to 20% are frequent due to periods of irregular rain distribution. Thus, water deficit is a major factor limiting citrus productivity. Transgenic plants of citrus rootstock Carrizo citrange constitutively expressing a Δ1-pyrroline-5-carboxylate synthetase mutant gene p5cs were developed to verify the tolerance of these transgenic plants to drought stress conditions. In this study, it was demonstrated that transgenic plants of Carrizo citrange expressing the p5cs gene accumulated high levels of proline. Transgenic plants exhibited osmotic adjustment upon soil drying and supported a longer period in severe conditions of drought stress (Molinari et al. 2004, Plant Science 167:6, 1375-1381). To help learn more about plant drought tolerance in perennial plants, Valencia sweet orange scions are being grafted on the transgenic rootstocks. This approach may explain whether proline could act as a component of signal transduction pathway that regulates stress responsive genes in plants. Furthermore, this study lays a foundation for future works that will be applied physiological and genomics studies to identify and characterise differentially expressed genes involved in citrus adaptation to drought stress when transgenic plants overproduce proline.
P 6.32 - Understanding functional relevance of drought stress induced cDNAs: a reverse
genetics approach using virus-induced gene silencing (VIGS)

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The emphasis of this study is to clone moisture stress responsive genes and assess their function by Tobacco rattle virus (TRV)-based VIGS approach. VIGS protocols were developed in Nicotiana benthamiana and tomato by silencing phytoene desaturase (pds) and RuBISCO small sub unit (rbcs). Heterologous gene sequences of pds and rbcs from different plant species were used to silence the expression of their respective homologs in N. benthamiana. Our studies confirm that heterologous gene sequences can be used to silence the target genes in related species as long as there is enough nucleotide homology. To study the stress responses, tomato stress responsive gene P5CS (coding for a key enzyme in proline biosynthesis) and groundnut lea4 (an ABA responsive gene) were silenced in tomato plants by TRV-based VIGS approach. Both P5CS and lea4 silenced plants showed enhanced levels of super oxide radicals, melondialdehyde and decreased membrane integrity and cell viability during drought stress. Osmotic adjustment and carbon assimilation rates were declined in P5CS silenced plants. Further, twenty five stress induced ESTs from groundnut were selected and its corresponding homologs were silenced in Nicotiana benthamiana. Under drought stress, the plants silenced for ESTs like GDI15 (a gene involved in flavonol biosynthesis), HSP70, salt inducible protein (SIP) and an aspartate kinase showed stress susceptibility. Interestingly, two other cDNA clones coding for aspartate proteinase and jmjc class transcription factor when silenced showed stress tolerance. Our results also suggest that functional significance of stress responsive genes can be assessed in heterologous plant species.

P 6.33 - Evolutionary linkage between drought and vegetative desiccation tolerance in plants

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Drought tolerance and desiccation tolerance have often been cited as manifestations of the same mechanism: desiccation tolerance being the extreme form of drought tolerance. However, there is a fundamental difference between drought and desiccation tolerance; drought tolerance mechanisms include ways of maintaining cell water content, such as osmotic regulation and stomatal closure, whereas desiccation tolerance consists of ways to survive the complete loss of water. It is clear that an evolutionary understanding of the relationship between drought and desiccation tolerance is necessary to determine which genes are adaptive in nature and which simply respond to secondary events such as cell injury. Our approach is to compare the expression profiles for genes in response to water deficits in drought sensitive species with their orthologues in desiccation-tolerant species during desiccation and within a phylogenetic framework. Our comparisons encompass a dicot to dicot pairing, a monocot to monocot pairing, and the comparison of both to the most primitive form of vegetative desiccation tolerance as manifested in the desiccation tolerant bryophyte Tortula ruralis. Initial comparisons between the water stress response of Arabidopsis and the desiccation response of Tortula have generated a solid baseline of similarities and differences that have generated the necessary hypotheses for our pair-wise comparisons. These data will allow us to focus attention on genes and gene networks that are truly central to cellular dehydration tolerance and may enable a more rational approach for the improvement of drought tolerance in crop species.
P 6.34 - Drought induced gene expression in Brazilian soybean genotypes

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Brazil is the second soybean producer in the world, however, drought events frequently cause great reduction in soybean production. Southern Brazilian states, responsible for approximately 40% of Brazil’s total soybean production, lost more than 30% production due to drought in the last two years (2004, 2005). Dehydration during drought triggers molecular events that result in physiological and developmental responses. Understanding these mechanisms and how they could be genetically manipulated to improve drought tolerance in commercial crops is one of the big challenges of agricultural researchers. Thus, the objective of this study was the isolation and expression analysis of genes up and down regulated in drought tolerant and drought sensitive Brazilian soybean genotypes during dehydration. Approximately 4.000 expression sequence tags (EST) induced during drought in soybean were cloned and sequenced. Comparison of these sequences with the sequences deposited in data banks allowed the identification of probable gene functions and the categorization of these ESTs. The identified categories include genes involved with cellular protection, transport, cellular structure, cellular division, gene expression regulation, cellular signaling and genes related to biotic and abiotic stress responses. Among these some are known as having differential expression during drought in other plant species, like Trehalose-6-Phosphate synthase, Trehalase synthase, Δ1-pirrolina-carboxilato synthase (P5CS), Dehydration Responsive Element Binding Protein (DREB), Aquaporin (PIP1) and Galactinol synthase. Detailed gene expression analysis using real time PCR indicated that a differential expression of some of these genes might be related with differences in physiological and agronomical responses to drought also analyzed during the experiments.

P 6.35 - OPTIWHEAT - Improving the yield stability of durum wheat under Mediterranean conditions

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Water is essential to sustaining human and environmental health but is already at scarcity level in some Eastern and Southern Mediterranean countries. Agriculture is by far the largest user of water resources accounting for around 75% of consumption, but nevertheless water remains a major determinant of crop yield. Under rain-fed conditions, characterised by low and uncertain rainfall, Durum wheat is one of the most widely cultivated crops. We are seeking use a powerful systems-biology approach combining genomics, crop physiology and agronomy to generate Durum wheat cultivars that have higher and more stable yields under Mediterranean drought conditions. The central thrust of the project is to both identify existing variation in Durum wheat germplasm and to generate novel genetic variation for the stability of yield under drought stress (SYDS) in Durum wheat. Our project will generate a novel mutant population and use these lines to establish Targeting Induced Local Lesions IN Genomes (TILLING) in Durum wheat. This population will be used for forward and reverse genetic approaches to identify lines with enhanced SYDS and to understand how the structure and expression of specific genes contribute to the variation of yield trait components under Mediterranean conditions. The projects major objective is to generate novel variation in a Durum wheat by random chemical mutagenesis and TILLING technology.
P 6.36 - Transcript profiling of contrasting rice genotypes and their recombinant inbred lines segregating for root penetrate through compacted soil

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Drought stress at the later stages of rice growth and development reduces rice production. Rice root penetration ability is an important trait for drought adaptation in areas with soils subject to both compaction and periodic water deficits. Rice genotypes, IR62266-42-6-2 and CT9993-5-10-1-M, are well documented for their contrasting drought tolerance traits, like osmotic adjustment capacity and root penetration ability through the compacted soil layer. CT9993-5-10-1-M and IR62266-42-6-2 have high and low root penetration ability, respectively. In this study, we monitored the transcription profile of these phenotypically divergent genotypes and six transgressive segregant recombinant inbred lines (RILs) for root penetration ability (three lines with the best and three lines the worst root penetration ability) using a high density oligonucleotide array with probes corresponding to ~21,000 genes. Between the two parents, 291 genes were differentially expressed. One hundred sixty seven transcripts were up-regulated in the high root penetration parent, CT9993, while 85 transcripts were up-regulated in the low root penetration parent, IR62266. On the other hand, 50 transcripts were down-regulated in the high root penetration parent, CT9993, while 27 transcripts were down-regulated in the high root penetration parent, IR62266. The differential expression patterns of transcripts and the regulatory networks will be presented.

P 6.37 - Structural and functional analysis of wheat based on expressed sequence tags (ESTs) related to abiotic stresses

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To study the structure and function of the wheat genomes, 7671 expressed sequence tags (ESTs), representative of unigenes, from 37 different Triticeae cDNA libraries were deletion bin mapped. A BLASTX search found that of the 7671 ESTs, 4,184 hit to the protein database Swiss Prot+TrEMBL, of which 278 (6.7%) could be linked to abiotic stress (heat, cold, drought, salinity, and aluminum). Of these, 259 abiotic stress-related ESTs were assigned to chromosome deletion bins and analyzed for their distribution pattern among the seven homoeologous chromosome groups. Most of the mapped ESTs fell into the category of enzyme activity (29%) followed by binding activity (27%). The B genome of hexaploid wheat contained the most stress-related EST loci in homoeologous chromosome groups 1, 3, 5, 6 and 7 but not in homoeologous groups 2 and 4. The D genome showed higher gene density, with chromosome 2D showing the highest relative gene density (1.41) in the entire genome. The centromeric bin of 5AL contained more than 50 percent of the stress-related loci, which were found primarily to be homologous to proteins associated with cold and salt response. A bin of importance to drought responsive and transcription factor-linked ESTs, 5BS8 8-0.56-0.71, had nine loci from two ESTs, one of which matched a hypothetical protein and the other, a protein with chaperone activity. Bin 4AS3-0.76-1.00 also contained an interesting abiotic gene cluster with 13 loci from 11 ESTs, which were similar in functional homology to the ESTs of deletion bin 4BL5-0.86-1.00, with similarity to osmoregulated protein sequences. In addition, the 259 Triticeae EST sequences were compared with the rice genome sequences.
P 6.38 - Expression of drought-related genes in Triticum and Aegilops

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Wheat productivity in many parts of the world is often limited by lack of available water necessary to maximise biomass and complete grain filling. Plants respond to water stress through physiological mechanisms at the cellular, tissue and whole-plant levels. These responses are not only dependent upon the severity and duration of the stress but also on the genetic background of the plants. Many studies indicate that wild progenitors of cultivars can be considered one of the major genetic resources of plant tolerance to stressful environments. Adaptation to drought requires protection of cells against dehydration through cellular responses either abrupt, as in the case of protein phosphorylation, or gradual, as in the case of changes in gene expression. A number of genes induced under drought conditions, such as dehydrins, have been identified. These genes respond experimentally to water stress, but their precise functions in either tolerance or sensitivity often remain unclear. Here we report the characterisation for drought tolerance of a collection of Triticum and Aegilops species, using physiological tests (free-proline content, RWC, WLR). Selection of genotypes contrasting in response to water stress was based on these tests. Selected genotypes were assayed by RT-PCR for the expression of genes for dehydrins, HSP101, and other drought-related genes under control and stress conditions. Differences between resistant and sensitive genotypes were detected mainly in the expression of some dehydrins and HSP101 genes. The present results indicate that these genes might have a functional role in the dehydration tolerance.

P 6.39 - Chloroplast protein synthesis elongation factor, EF-Tu, and drought and heat tolerance in maize (Zea mays L.): EF-Tu function and expression under stress conditions

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Chloroplast protein synthesis elongation factor, EF-Tu, is a highly conserved, nuclear encoded protein (45 - 46 kD) that plays a key role in protein synthesis. This protein binds GTP and aminoacyl-tRNA and leads to the codon-dependent placement of this aminoacyl-tRNA at the A site of the ribosome. Chloroplast EF-Tu is encoded by a multiple gene family, as multiple copies of the EF-Tu gene have been found in several species. Recent studies have suggested that chloroplast EF-Tu may play a role in the development of drought and heat tolerance. We investigated the expression of EF-Tu gene(s) in drought and heat tolerant (ZPBL 1304) and drought and heat sensitive (ZPL 389) maize (Zea mays L.) lines during early stages of their development (5 to 21-d-old plants). In addition, we also investigated the expression of EF-Tu gene(s) in mature plants of these two lines under field conditions. In the drought and heat tolerant line, plants of all ages (except 5-d-old plants) showed heat-induced accumulation of both EF-Tu transcript and EF-Tu protein. In contrast, in the drought and heat sensitive line, only plants of up to 14 d of age displayed increased accumulation of EF-Tu under heat stress. Interestingly, increase in the relative level of EF-Tu in the drought and heat sensitive line was not preceded by increase in the steady state level of EF-Tu mRNA. The results suggest that under stress conditions the expression of EF-Tu gene(s) may be different in these two maize lines.
P 6.40 - High-throughput analysis of genes supporting plant performance under drought stress


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Molecular research of stress responses in plants has traditionally been focused on unravelling the genes, proteins and LMW components that allow survival under potentially lethal environmental conditions. However, in the context of crop cultivation, it is often more relevant to elucidate and improve the mechanisms that control the maintenance and/or recovery of growth during and after mild environmental stress. Research in this area is hampered by the difficulties to monitor and dissect the kinetics of growth and yield processes in soil-grown plants. CropDesign has developed a high-throughput platform, named TraitMill™ for testing the effects of single genes on growth processes in rice. Growth is evaluated under various conditions, including drought stress. Drought is imposed during flowering and seed filling, which are the developmental stages most sensitive to water deficit. Details on the set up of the drought screen will be presented, together with data on transgenic plants with increased performance under drought stress.

P 6.41 - Arabidopsis encyclopedia using full-length cDNAs and its application for expression profiling under abiotic stress conditions

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Full-length cDNAs are essential for the correct annotation of genomic sequences and for the functional analysis of genes and their products. We have constructed full-length cDNA libraries from Arabidopsis plants and isolated 224.641 RIKEN Arabidopsis full-length (RAFL) cDNA clones. They were clustered into 18.127 nonredundant cDNA groups, about 70% of predicted genes1). We have determined full-length sequences of 15.240 RAFL cDNA clones as of March 1, 2005). We have also used the RAFL cDNAs for the microarray analysis3) of expression profiles, and the functional and structural analysis of Arabidopsis proteins. Regulatory genes, such as transcription factors, protein kinases and F-box proteins play critical roles in all aspects of higher plant's life cycle. It is valuable to learn how the regulatory genes are expressed and regulated at the whole-genome scale. Therefore, we prepared Arabidopsis whole-genome regulatory gene oligo DNA microarray containing all transcription factors, protein kinase and F-box protein genes in Arabidopsis genome recently. The 60-mer oligo DNA corresponding to 1.979 transcription factors, 1.060 protein kinase and 551 F-box protein genes are spotted on slide glass as a custom array of Agilent Co. In this meeting, we present expression profiles of regulatory genes in various stress and hormone treatments, and various plant tissues using the Arabidopsis regulatory gene oligo DNA microarray.

P 6.42 - MAPKs expression pattern under drought stress in bread wheat

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Plant productivity is greatly affected by drought stress. Studying the expression feature of protein kinase genes is of great importance to elucidate the mechanism of plant molecular response to drought stress. Mitogen-activated protein kinase (MAP kinase) is important mediators in signal transmission, connecting the perception of external stimuli to cellular responses. For evaluate MAPK's expression pattern in bread wheat under drought stress, seeds of wheat (Triticum aestivum L. var. Tabasi) were germinated in vitro on normal osmotic potential medium. After three days, seedlings were exposed to severe drought stress, produced by adding PEG6000. Roots total RNA was isolated & mRNA was purified at different times from each treatment. Primers corresponding to MAPKs consensus regions were designed and used in amplifications of single strand cDNA. PCR products displayed on denatured sequencing gel, showed different patterns of MAPKs expression in different treatments. Polymorph bands have been isolated from gel and sent for sequencing.

P 6.43 - Characterization of transcription regulatory networks of maize root regions under water deficit conditions

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Under conditions of drought, plant roots can adapt to continue growth while at the same time producing and sending early warning signals to shoots, which inhibit plant growth above ground. A high density maize oligo array was used to characterize the transcript profiles in the growth zone of well-watered and 48h water-stressed maize primary roots to discover region-specific responses to water deficits. The expression profiles were compared to identify genes contributing to root growth maintenance (region 1), programming root growth inhibition (region 2), that responding to water deficits, as well as the gene expressions that are in common or differential between root regions with developmental controls (WS48 vs. WW24 region 1; WS48 region 2 vs. WW48 region 3), and temporal controls (WS48 vs. WW48 region 1; WS48 vs. WW48 region 2). Most of these differentially displayed genes have been previously implicated in other plant species under water deficits, whereas others may reflect novel pathways or genetic content involved in maize root growth maintenance or growth inhibition. To well understand the transcriptional regulatory mechanisms of root growth maintenance and growth inhibition under the severe water deficits, it is imperative to find the transcription regulatory networks which initiate plant response and adapt the drought conditions. Abiotic stress related transcription factors and the DNA binding domain or motif were blasted against the genomic sequences corresponding to transcript sequences differentially displayed under water deficit conditions. Comparison of transcript levels of these TFs and their targets over a time course using qPCR and the predication of gene expression patterns and regulatory networks will be presented.
Dehydration-related stresses such as drought, cold and salinity are major constraints to legume production around the world, affecting not only the plants themselves but also Symbiotic Nitrogen Fixation by legume root nodules. Understanding the mechanisms distinguishing tolerant from susceptible reactions to dehydration stress could improve breeding for stress tolerance and thus, would have tremendous impact on the productivity of legumes everywhere. Major insights into mechanisms governing tolerance of crops to dehydration stresses could come from comparing whole-genome transcription profiles from tolerant and susceptible varieties under stress, and relating the responsive loci of the different crops to each other and to genes and genetic maps of the model legumes via comparative mapping. Thought to be ambitious until now, this approach recently became feasible due to the advent of SuperSAGE (Matsumura et al. 2003, patent pending), a SAGE-based, highly reliable, whole-genome transcription profiling technique which, as an open-source methodology, allows to efficiently analyse the transcriptomes of all eukaryots. SuperSAGE generates 26bp long tags from defined regions of cDNAs that are concatenated and sequenced, rendering SuperSAGE 20-25 times more efficient than EST sequencing. Tags can be reliably annotated in the data base and used for the amplification of cDNA ends by 3'- or 5'-RACE. Allelic variability of 3'-RACE products is determined by EcoTILLING (Comai et al. 2004) with Cel1 nuclease and allelic variants are genetically mapped. Since polymorphic cDNA ends represent genic markers, their map position can be compared between the different legume crops and to the arising physical maps of the model legumes which could serve as bridges between different crop genomes. Here, we explore the pros and cons of this appealing concept using drought and salt stressed tissues from chickpea as an example.

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P 6.45 - Expressing JERF3 in tobacco enhances drought tolerance and displays differential responses to abscisic acid during development stages

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Plants are constantly exposed to abiotic and biotic stresses during plant growth and development. Several plant hormones, such as ethylene, ABA, JA play a crucial role in altering plant morphology in response to stress, which will further regulate the expression of multiple stresses responsive genes. Previously, we reported that a tomato ERF transcription activator that binds to GCC box and DRE, JERF3, was induced by ethylene, JA, cold, salt and ABA, suggesting that JERF3 might act as a linker among ethylene, JA and osmotic signal pathways. We now report that the regulatory role of TERF1 in ABA and drought responses during seed germination and seedling development. Firstly we confirmed that TERF1 activated the expression of GCC box- and DRE-driven reporter in transient expression assay, respectively, subsequently increasing the tolerance to drought in tobacco expressing JERF3. And this increase of drought tolerance in transgenic tobacco was associated with the lower rate of water transpiration, high sensitivity of stomatal movement to ABA application, higher ABA content and the constitutive expression of some downstream genes responsive to ABA and osmotic stress. Further tests showed that JERF3 enhanced the seed germination, and decreased the sensitivity during tobacco root elongation under ABA and mannitol treatments, demonstrating that JERF3 integrates not only multiple stress signal pathways, but also displays differential responses to ABA in plant development stages.

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P 6.46 - Genetic transformation of stress responsible genes and testing of drought tolerance in rice

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With a long-term goal of improving drought tolerance of irrigated rice, this study was initiated to test the effectiveness of functionally-characterized drought stress responsible genes (candidate genes) in improving drought tolerance by genetic transformation. These candidate genes, mostly from Arabidopsis, encode proteins involved in various aspects of stress responses and adaptation including transcriptional regulation (CBF3/ DREB1A, ZAT10), ABA synthesis (LOS5, NCED1), ion homeostasis (SOS2, NHX1/2), detoxification (NPK1) and osmotic protection (HVA1). Meanwhile, the full-length cDNAs of rice homologues to these candidate genes (six for CBF/ DREB, two for HVA1 and one each for NHX1, NPK1, SOS2) were isolated. All these candidate genes and rice homologues were constructed under the control of constitutive promoters (CaMV 35S or Actin1 promoter) and stress inducible promoters (LEAP isolated from rice) respectively and introduced into rice cultivar Zhonghua11 by Agrobacterium-mediated transformation. At present, more than 100 independent transgenic families for each construct of the candidate genes and more than 40 independent transgenic families for each construct of the rice homologues have been generated. Thirty independent transgenic families (most of them with single copy of transgene) of each construct, 20 plants each family, were tested in PVC pipes (for drought tolerance) and in field under a rain-off shelter (for drought resistance) respectively at reproductive stages in year 2005. In addition, salinity tolerance testing was also conducted for genes NHX1, SOS2, NPK1, LOS5, and NCED1. The data of drought or salt tolerance performance of these transgenic plants will be presented in the meeting.

The work was supported by a grant from the Rockefeller Foundation.
**P 6.47 - Isolation and characterization of critical genes for drought tolerance in rice using integrated approaches**


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Drought tolerance has very complex genetic background with distinct molecular and physiological mechanisms in different plant species. Irrigated rice has been domesticated in a full irrigation ecosystem and become extremely sensitive to drought. With a long-term goal of improving drought tolerance in irrigated rice, isolation and characterization of critical genes for establishment of drought tolerance in rice has been targeted using three approaches. (1) Mutant screening. More than five thousands of T-DNA insertion lines were screened for drought tolerant, drought sensitive or ABA-insensitive mutants. So far five drought sensitive, two drought tolerant, and three ABA-insensitive mutants were identified and the corresponding genes have been isolated. (2) Reverse genetics. Genome-wide gene expression profiling was performed to identify genes involved in drought response and adaptation. Dozens of drought responsive genes (most of them with unknown function) were under molecular characterization and genetic transformation in rice. Among them, putative transcription factors and protein kinases were emphasized. Overexpression of a few drought responsive transcription factors have significantly improved both drought and/or salinity tolerance in rice. (3) QTL cloning. The morphological (such as deep root) and physiological (such as OA) traits for drought resistance are under investigation and near isogenic lines for three QTLs of deep root and one QTL of OA are generated for gene cloning and marker assisted molecular breeding.

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**P 6.48 - Yield response to water gradient in a rice population: associations among traits and genetic markers**


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Drought is a major constraint to rice (*Oryza sativa* L.) production in rainfed and poorly irrigated environments. Grain yield and its components of a RI population under different water levels in 2003 and 2004, were investigated in an rainout drought tolerance screening facility in Shanghai. A total of 32 Quantitative Trait Loci (QTL) were identified. The phenotypic variation explained by individual QTLs ranged from 7.45 to 34.85%. There was high genetic association among yield traits in both water conditions. Path analysis indicated that percentage fertility was particularly important for grain yield with direct effect (P = 0.6045) on grain yield in water stress, while spikelet number per panicle (SN) determined grain yield with direct effect (P = 0.4087) under well-watered conditions. Several main QTLs affecting percentage fertility, grain weight, panicle number, and SN mapped to the same locus on chromosomes 4 and 8, respectively. These QTLs were detected consistently across two years and under both water levels in this study. Close linkage or pleiotropy was widely found. The QTLs located at the marker intervals RM_526-RM_6, RM_132-RM_231, and RM_241-RM_349 on chromosomes 2, 3 and 4 resulted in higher grain yield. Several candidate genes were cloned based on the mapping results. The identification of genomic regions associated with GY and its components under stress will be useful for marker-aided approaches to improve drought tolerance of rice.
P 7.01 - Progress in developing cultivars with improved yield under reproductive-stage stress in upland and lowland rice

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Reproductive-stage drought tolerance is a major IRRI breeding objective. Over 1,000 advanced lines were evaluated for yield under stress in 2005. Screening is conducted in the dry season (January-April), when rainfall averages less than 200 mm. Stress is imposed repeatedly after maximum tillering, with irrigation when soil water tensions at 15 cm reach - 50 and -70 kPa in lowland and upland trials, respectively. Sensitive genotypes yield less than 0.5 and 1 t ha⁻¹ in upland and lowland screens, respectively; or half as much as highly tolerant materials. Reference lines with large, repeatable differences in yield under stress have been identified and are useful in characterizing actual stress levels achieved. Preliminary evidence indicates that the protocol predicts performance under natural reproductive-stage stress in the wet season. Lines combining high yield potential with tolerance have been identified. Unselected population means under stress are strongly associated with mid-parent yield; at least one tolerant parent should be used in crosses aimed at improving stress yield. F1 hybrids are significantly more tolerant than inbreds under lowland stress, out-yielding them on average by 0.9 t ha⁻¹, or 50%. Selective genotyping studies are also underway to locate QTLs with large additive effects on stress yield in 11 crosses of tolerant with susceptible parents. No such loci have been repeatably detected to date. Our results indicate that genetic control of tolerance to reproductive-stage stress in rice is polygenic, and confirm that gains are achieved when populations with a tolerant parent are directly selected for yield under stress.

P 7.02 - Canopy temperature depression and drought response in winter wheat: Optimal time of sampling for the yield prediction and genotypic differentiation

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Canopy temperature (CT) and canopy temperature depression (CTD), the difference between air temperature and CT, have been proposed as useful tools for revealing genotypic variation in crop tolerance to heat and drought stress. However, sampling time for the best yield prediction and genotypic differentiation is not clear yet. We used nearly continuous CTD readings, obtained from three closely related winter wheat lines with differential yield response to water availability, to assess the optimal time of CTD sampling. Measurements of CTD were taken in 2000, 2001 and 2002 during wheat vegetation cycles at Bushland, Texas. ANOVA indicated significant differences for CTD among the genotypes in all years at all stages of development. Regression tree analysis revealed that the best estimates of yield from CTD measurements were from anthesis until three weeks post-anthesis, and that the time to differentiate genotypes was at anthesis. Cluster analysis and multiple linear regression revealed that night time as well as day time CTD sampling is required for best yield estimation under dryland and irrigation. Results allow us to improve our use of CTD as a screening tool for higher yield under drought, but also to identify limitations.
P 7.03 - Exploration of genetic variation in relation to drought tolerance in olives (Olea europaea L.)

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Water requirements of agricultural crops have been studied in many crops. These data are, however, usually measured at the crop level through the use of crop coefficient (Kc) at different growth stages. This work intends to focus on the intraspecific diversity i.e. at genotype (Kg) level to explore the olive genetic diversity in relation to drought tolerance based on the whole plant approach. Gas exchange characteristics were measured on more than 20 olive cultivars from different origins in spring, summer, autumn and winter of 2003-2004. Seasonal patterns and tendencies revealed a wide range of variation due to the variation among the cultivars studied. The results indicate that these different cultivars behave differently to lower their Kg by either closing their stomata in summer (dry) while others regulate in a non linear pattern their stomatal properties. The results indicate also tremendous diversity in terms of root architecture properties among the cultivars studied. Intriguingly, when contrasting gas exchange parameters with those of root structure parameters early high root branching occurred in some of the cultivars that use water more efficiently than others. This corroborates earlier findings where the early triggering of a water use strategy, such as that of early branching of roots, leads to more efficient use of water, particularly in areas where prolonged drought prevails. The study will continue the phenotyping and assessment process for rapid screening to develop a drought-tolerant collection of olive cultivars and rootstocks and to seek synergy from the combination of the different techniques.

P 7.04 - Post anthesis drought tolerance in wheat : Evaluation and molecular mapping

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Wheat is the first important and strategic cereal crop for the majority of world’s population. It is the most important staple food for about two billion people. World production is limited primarily by environmental stresses of which post-anthesis drought is a serious problem. Tolerance against drought has been defined in several ways and the lack of a simple screening procedure has slowed the selection of improved genotypes. Using a chemical desiccation method (KI) 10 to 14 days after flowering, wheat germplasm of the Gatersleben genebank and two wheat mapping populations were screened. Quantitative trait loci (QTL) analysis was carried out using a set of 114 recombinant inbred lines (RILs) from the International Triticeae Mapping Initiative (ITMI) population created by crossing the synthetic hexaploid wheat ‘W7984’ (tolerant) with the spring wheat cultivar ‘O’pata 85’ (sensitive). ‘W7984’ was generated via a cross of an Aegilops tauschii accession (genome DD) with the tetraploid wheat ‘Altar 84’ (genomes AABB). In addition, 81 F2:3 families from the cross ‘TRI 5283’ (tolerant) x ‘TRI 15010’ (sensitive) were investigated. In two experimental years in Gatersleben, the amount of dry matter stored and mobilized was estimated by measurement of changes in 1000-grain weight after chemical desiccation treatment. Genomic regions controlling traits related to post-anthesis drought tolerance were identified.
P 7.05 - Drought tolerant roses in Hungary

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The climate of Budapest is basically continental. The years 2002-2003 were extremely droughty, the high temperature and the lack of the spring rains were critical. In these years, 120 rose varieties, which are suited for public parks were examined in the Rose Garden - Budatétény. We looked for shock tolerant roses. The plants did not receive watering, shading and herbicide spraying in summer. The best flowering varieties from the first flowers to the frosts were the following in 2002: Polyanthas: 'Domokos Pál Péter', 'Verecke', and 'Déva'. Floribundas: 'La Sevillana', 'Munkács', 'Szent Margit'. Climblings: 'Clg.Gertrud Westphal', 'Vörössipkások', 'Szent Erzsébet'. In midsummer, under very arid conditions, the blooming results were the following: none of the climbing roses were in bloom. The best floribunda was 'La Sevillana'. It could produce extremely good results throughout the whole summer. 'Szent Margit' and 'New Daily Mail' were also very good. Among the polyanthas 'Domokos Pál Péter' was the best and 'Táncsics Mihály' was very decorative as well. Polyantha roses were more suitable for the long-lasting, dry summers than the floribundas, because they were in bloom much longer. In the year 2003, the masses of foliage were ranked. The varieties with densest foliage were the followings: Polyanthas: 'Happy', 'Orange Triumph Improved', Floribundas: 'Szabó Dázs ', 'Laborfalvi Róza', Climblings: 'János vitéz', 'Szent Erzsébet'. Hungarian roses proved to be very good in droughty summer weather. Nevertheless, there was no variety, where the best flowering ability and the best foliage could be found together. There are some really robust roses with good foliage, 'János vitéz' were the best among them. Out of all the 120 varieties, in midsummer 'Domokos Pál Péter', a Hungarian robust Polyantha rose was probably the best.

P 7.06 - Enhancing drought adaptation in sorghum: combining 'gene-to-phenotype' and 'phenotype-to-gene' approaches

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Connecting breeding, physiology and molecular biology to develop cereals that are better adapted to drought will assist crop scientists to produce more grain with less water. In many areas of human endeavour, it is often the integration of fields of knowledge that proves to be the fertile ground for innovation. So it is with 'gene discovery' in the world's most important cereal crops. The pursuit of drought-resistance genes in sorghum is a multi-disciplinary effort involving plant breeders, crop physiologists and molecular biologists. An international partnership involving scientists from Australia and the U.S. is searching for genes (Stg1, Stg2, Stg3 and Stg4) associated with the 'stay-green' trait in grain sorghum. Keeping leaves alive for longer is a fundamental strategy for increasing crop production, particularly under water-limited conditions. During post-anthesis drought, genotypes possessing stay-green maintain more photosynthetically active leaves than senescent genotypes. The broad objective of this research is to identify and understand the functional physiology of the trait and the function of genes and gene networks that contribute to it. Physiological dissection of plant function and map-based gene cloning are the primary approaches to gene discovery in this project. Multiple cycles of phenotyping and genotyping have enabled scientists to simultaneously close-in on the processes involved and the genes of interest. Further fine-mapping will ultimately lead to the discovery of the genes involved. Discovery of gene function will enhance existing capacity for assessing trait value in a range of environments in silico using crop simulation modelling. This integrated approach will enable plant breeders to more efficiently custom-make sorghum varieties for specific water-limited environments.
P 7.07 - Improving terminal drought tolerance in breadwheat by physiological and molecular genetic approaches

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Water is strongly limiting in rain-fed broadacre farming systems in Australia. In Western Australia (WA) for example, crop production is limited by water supply each year with terminal drought as the major characteristic of the environment. In many irrigated regions, terminal drought is also unavoidable, due to limited groundwater. Findings of consistently high values for stem carbohydrate concentrations at flowering in WA wheat varieties have made evaluation and development of marker assisted selection for stem carbohydrates the highest priority for drought tolerance selection in WA. The objectives of the present study are to evaluate the impact of stem carbohydrates on drought tolerance at grain filling stages (terminal drought), map the genes responsible for the accumulation of stem carbohydrates, and initiate a germplasm improvement program. Two DH populations, Westonia/Kauz and Westonia*2/Janz, were studied in natural (control) and in a rainout shelter (drought) in the field. Samples for stem carbohydrate analysis were taken at anthesis. At full maturity 10 mainstem heads and the remaining tiller heads were harvested for the comparison of grain yield between control and drought treatments. Grain yield in the control and drought treatments from over 4,000 plots harvested in 2004 showed that there was no significant difference between treatments mainly due to insufficient rainfall during grain filling. The analysis of grain yield data showed good variation within the populations with a genetic diversity for grain yield of about 3-fold under drought conditions equivalent to between 0.2 to 2 t/ha grain yield. Preliminary carbohydrate data will also be discussed. Results from 2004 indicate that for reproducible, controlled screening protocols for terminal drought in rain-fed environments, irrigation facilities are essential to (i) eliminate pre-anthesis water deficits in all treatments and (ii) supply water equivalent to a “normal season” during grain filling in control treatments. Irrigation facilities have been installed for replicated drought tolerance screening of approximately 600 genotypes in 2005. For quantitative trait loci analysis of terminal drought 78 markers have already been mapped in Westonia/Kauz population. Further mapping and QTL analysis results will be discussed.

P 7.08 - Impact of canopy architecture on water stress in sunflower crop

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The improvement of crop water use efficiency has received more attention through crop management than genetics. Canopy architecture, partially genetically determined, drives light interception and affects the energy use of the crop. Thus, differences in leaf area or leaf spatial disposition affect the crop water use. Crop water consumption is driven by transpiration, which governs carbon assimilation, so reducing the crop water consumption means lowering the amount of biomass produced. The aim of this study was to quantify the impact of major architectural traits (total leaf area, position and area of the largest leaf, light extinction coefficient) on transpirable soil water for contrasted climatic and irrigation scenarios. The CO2/water trade-off was taken into account by using a crop simulation model for sunflower (Helianthus annuus L.) genotypes. A water stress index (WSI) was built from the fraction of transpirable soil water. Then, a sensitivity analysis was conducted to quantify the response of WSI to variations of each architectural trait within an observed range. Phenotypic variability of these traits was observed on 13 sunflower genotypes over 4 years (2001-2004) and 2 locations (Montpellier, Toulouse). Each trait led by itself to contrasted water use patterns (date of stress occurrence, stress intensity) and interactions were observed with water availability (weather, irrigation). This approach allowed to identify optimal combinations of architectural traits which would lessen crop water stress (and increase WUE) under a given climatic scenario.
P 7.09 - Phenotyping maize for drought response in Brazilian tropical areas: approaches to breeding programs and genomics studies

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Phenotyping or genetic resources characterization has been an essential breeding program component and now is becoming a key complement to genotyping in molecular breeding investigation. In Brazil, most important crops breeding programs have already involved the plants' adaptation to adverse or unfavorable prevailing environmental conditions in the tropics by taking into account multiple stresses. Generating new high yielding genotypes tolerant to high soil aluminum, low phosphorus availability, drought, and more efficient in nitrogen utilization (non biotic stresses) has continuously been a challenge for breeding. The drought is one of the most important sources of cereal grain production instability among them. A low heritability for yield and yield related traits has been pointed out in many works. Thus, a good selection criteria in breeding programs might be identify characteristics and mechanisms related to environment stress tolerance in order to generate better adapted genotypes with higher yields. Previous research results towards effective phenotyping for drought have showed that some measurements are fundamental for the water stress characterization, grain yield evaluation, and secondary yield traits selection in field and greenhouse conditions. The following key points must be defined for drought phenotyping studies: a) Which phenotypic parameter better describe drought stress; b) Characterization and description of the site-specific; c) Measurements of the soil and plant water status; and, d) Critical crop growth stage for water stress tolerance. The strategy, techniques and goals for identifying and characterizing maize genotypes for drought tolerance in tropical conditions are presented. The utility of our phenotyping platform as a support to the generation of knowledge and information for conventional breeding programs or molecular breeding approaches as complement to genotyping is discussed.

P 7.10 - Participatory varietal selection for development and adoption of rice lines for rainfed ecosystems

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Adoption of improved rice varieties is slow in rainfed environments. In such environments, traditional breeding approaches for development and adoption of improved rice varieties have not been very effective hither to. Participatory varietal selection (PVS) is relatively a rapid approach to develop and disseminate improved varieties. A set of 14 advanced rice cultures along with local check were evaluated in three mother trials in three different villages in the target environment. A subset consisting of three cultures along with the local check was evaluated in four baby trials in villages surrounding each mother trial during 2004-2005. The same set was also evaluated at Agricultural Research Station, Paramakudi. Local farmers were asked to score different cultures in each trial. Scoring was given between 1 and 5 based on their own preferences. The most preferred culture was scored with 5 while, 1 for least preference. Plant height, duration, grain quality, drought tolerance, grain yield, straw yield and overall acceptability were the traits scored for. The culture PM 02 015 was found to be superior in majority of the trials. In the on-station trial, Kendall's' coefficient of concordance (Kothari 1990) among farmers was significant for all the traits which indicated that farmers ranking was not random and maximum sum of ranks was scored by the culture PM 02 015 for grain yield. The study indicated that advanced stage cultures are highly acceptable by farmers. Participatory approaches can be usefully integrated at several points in rainfed rice breeding program.
P 7.11 - Identification of drought resistant genotypes using wet season field screening in rainfed lowland rice

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Rainfed lowland rice is grown in highly heterogeneous drought-prone environments in Asia and grain yield is often reduced due to drought. However, development of drought resistant varieties has been slow, at least partly because of lack of reliable screening method. Under ACIAR and Rockefeller funding we have developed a simple cost effective field screening method for determination of drought resistant lines in Thailand, Cambodia and Lao PDR. Uniform drought conditions are developed by delaying time of sowing to reduce the chance of heavy rainfalls during screening, and draining water sometime after transplanting. Flowering delay, leaf water potential, spikelet fertility and grain yield are collected from both drained and irrigated experiments and used as selection criteria for drought resistance. The results in the total of 52 wet season drought-screening experiments conducted in the region in five years show that 31, 26 and 43%, respectively, of experiments achieved yield reduction of <15%, 15-40% and >40% of the grain yield obtained under irrigated condition. Grain yield under drought condition adjusted to potential yield and flowering date under irrigated condition (drought response index) has been found to be the most useful index for selection of drought tolerance. Some genotypes selected have performed well consistently across different drought conditions and they are currently being further evaluated.

P 7.12 - Brown spot a biotic stress associated with water limited conditions in rice

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Helminthosporosis or brown spot disease of rice is widespread and occurs in all rice growing countries of the world. It causes heavy losses, particularly in the leaf-spotting phase, when it reaches epidemic proportions. The disease in Chhattisgarh is confined to rainfed areas, which are poor in fertility status in general, and depletion of nitrogen in particular. Rainfed low lands are prone to soil problems then other rice growing areas because drying of the soil adversely affects the availability of nutrients. Rainfed lowland conditions, which usually entail alternate wilting and drying of the soil, are conducive to a range of mineral stresses. Drying may increase N losses through mineralization of nitrogen in unfertilized fields and denitrification in many lowland soil types. Research on Cochliobolous is well justified by its pathogenic importance. Cochliobolus miyabeanus (H. oryzae) contributed to Bengal famine of 1943, which arose concerns for the genetic vulnerability of our food plants and resulted in huge yield losses, extending as high as 90% in certain areas. Very little information is available on the inheritance of resistance to this disease. Report on the inheritance of resistance for this disease is meager. Conventional genetic studies have provided little information on the inheritance of genes controlling the resistance. The double haploid population derived from CT 9993-5-10-1-M / IR 62266-42-6-2 provides a good basis to study and to analyze genetically the complex and polygenic forms of disease resistance known as “Quantative trait loci” (QTL) associated with brown spot disease of rice. Putative QTLs associated with brown spot resistance were identified. Three QTLs (above 2.30 LOD value) were on Ch # 2, 6 and 12, and four QTLs (above 3.00 LOD values) on Ch # 4, 8, 6 and 1. The QTLs explained a total phenotypic variation from 6.8 to 20%. A close correspondence between genomic locations between the putative QTLs detected in the present study with that of the previous mapping results was observed. Twelve markers out of thirty-four screened were found polymorphic among the parental lines CT 9993-5-10-1-M / IR 62266-42-6-2 and selective genotyping, indicated that RM 556, to be linked with the putative QTL (associated with resistance to brown spot) on Ch # 8. Co-segregation analysis confirmed the close association of putative QTL associated with RM 556. The single marker analysis following 't' - test based on the marker data further indicated, a close association of the RM 556 and RM 32 with that of the putative QTL on the Ch # 8.
P 7.13 - The evaluation of panicle exsertion, leaf rolling, and leaf drying as indirect selection criteria for yield under severe reproductive-stage upland stress in two tolerant x susceptible rice mapping populations

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Two populations of 450 lines from crosses between a highly tolerant upland parent, IR55419-04 and highly susceptible parents IR 64 and Way Rarem were screened to evaluate the secondary traits panicle exsertion, leaf rolling (LR), and leaf drying (LD) as indirect selection criteria for yield under severe upland stress. Populations were screened under severe intermittent stress in a direct-sown upland field during the 2004 dry season, and in a well-watered upland control. Stress was imposed starting 45 days after sowing by withholding irrigation for repeated cycles of about 10 days, irrigating when tensiometer readings fell below -60 kPa at 15 cm depth. LR and LD were recorded twice at weekly intervals after the second stress cycle. Stress reduced the population yield from 129.41 to 23.06 g m⁻² (82%) in IR55419-04/Way Rarem, and from 82.35 to 27.18 g m⁻² (67%) in IR55419-04/IR64. The tolerant parent yielded an average of 33.6 g m⁻² under stress, whereas susceptible parents IR64 and Way Rarem yielded 5.4 and 9.2 g m⁻², respectively. Heritability (H) for stress yield was 0.45 and 0.48 in IR55419-04/Way Rarem and IR55419-04/IR64, respectively. Although stress was severe, genetic correlations for yield across water regimes were positive, indicating that lines combining tolerance and high yield potential can be selected. Some lines out-yielded the tolerant parent by 150% under stress. Panicle exsertion was moderately genetically correlated with yield under stress, but its H was not higher. Genetic correlations of stress yield with LR and LD were low. These traits are therefore not useful indirect selection criteria for yield under severe stress. These populations are now being selectively genotyped to detect QTLs with major additive effects for yield under stress.

P 7.14 - Phenotypic and genotypic evaluation of Hordeum spontaneum derived lines for adaptation to drought stress conditions: an international collaboration between ICARDA and Australia

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Barley is one of the most important crops in many developing and some developed countries, such as Australia. In these countries, barley yield is largely affected by drought, which can be as severe as to cause crop failures. Wild barley is a potential source of useful genes for the development of improved varieties with good adaptation to drought stress. The objective of this work was to test the hypothesis whether specific chromosomal regions of H. spontaneum are responsible for the adaptation to drought. Fifty-nine barley lines carrying various levels of introgression from H. spontaneum were tested in replicated field trials, under low rainfall conditions in Syria, and genotyped with 50 simple sequence repeats (SSRs). The amount of variability between the wild barley derived lines and improved varieties was relatively high for important developmental and yield related traits. The best performing wild barley derivatives out yielded the Syrian improved landrace variety Tadmor by 7.2-23.8% and the Australian feed barley varieties Keel and Barque by 5.2-17.1% in the location (Breda) where drought stress was most severe. The molecular analysis using SSR markers revealed that chromosomes 1H, 2H, 3H, 4H and 7H had the highest percentage of shared alleles with H. spontaneum, linked to important yield and developmental traits. SSR markers 14079 (55.9%) followed by Bmac0581 (54.2%) and Bmac0213 (49.2%) contributed the highest percentage of shared alleles. The performance of wild barley derived lines suggests that H. spontaneum is a useful source of genes for the improvement of cultivars better adapted to low rainfall environments.
P 7.15 - Testcross evaluation of root-ABA1, a major QTL influencing root architecture and ABA concentration in maize

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A previous study on a maize mapping population derived from Os420 × IABO78 identified a major quantitative trait locus (QTL) for leaf-aba-sisic acid concentration (L-ABA) on chromosome 2 (Tuberosa et al. 1998, T.A.G. 97:744-755). The QTL near csu133 on bin 2.04 accounted for 32% of the total variation for L-ABA. At this QTL, Os420 and IABO78 carry the alleles increasing (high/high) and decreasing (low/low) L-ABA, respectively. To characterize more accurately the direct and associated effects of this QTL, sets of backcross-derived lines (BDLs) were developed for both parental lines. The per se evaluation of the BDLs validated the effect of the QTL on L-ABA and showed a significant effect of the QTL also on root traits (Landi et al. 2005, Mol. Breed. 15:291-303). Based upon such results, a model was presented to account for the effects of the QTL on L-ABA and other traits. This model postulates that the primary action of the QTL is on root architecture and size which, according also to water availability, in turn affect L-ABA and other traits. For this reason the QTL has been named root-ABA1. The objective of this study was to evaluate the effects of root-ABA1 in testcross combination. One set (high/high L-ABA and low/low L-ABA) of BDLs in the IABO78 background was crossed with 13 lines developed in China. The 26 testcrosses were field-tested (3 reps) under well-watered and drought-stressed conditions in Western China (Urumqi). On average, the yield of the well-watered and drought-stressed treatments were equal to 211 and 75 g/plant, respectively. Significant differences due to the effects of root-ABA1 were detected for all investigated traits except for flowering time and anthesis-silking interval. On average, the testcrosses with the high-root-ABA1 allele, as compared to the testcrosses with the low-root-ABA1 allele showed a significant decrease in plant height (-1%), ear height (-2%), vegetative biomass (-10%), total biomass (-9%), ears/plant (-9%), harvest index (-2%), kernel weight (-1%), kernels/plant (-8%) and grain yield (-9%). The significant "BDL x tester" interactions that were detected for all the previous traits (with the exception of ears/plant) were mainly due to scale effects. Our results confirm the main features of the model suggested in Landi et al. (2005), where the high-root-ABA1 allele, as compared to the low-root-ABA1 allele, was postulated to affect negatively grain yield through a reduction of fertility in relation to an excess of ABA production at the root level consequent to a larger and more superficial root system. Our findings are in accordance with such model, also in consideration that the yield of the high-root-ABA1 testcrosses was more negatively affected under drought conditions (-15.5%) as compared to well-watered conditions (-7.7%). It is well known that ABA production increases under conditions of water deficit. The positional cloning of root-ABA1 is in progress. A large mapping population derived from the cross of two BDLs has been produced in both parental background and the F4 families homozygous for the recombination event (segmental BDLs) will be tested this summer for the fine mapping of root-ABA1.

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P 7.16 - Genetic networks underlying drought tolerance in rice: detection, verification and application in breeding

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A series of systematic genetic studies were conducted to understand the genetic basis of drought tolerance (DT) in rice. First, the genomewide responses of 794 rice introgression lines (ILs) from 68 BC2F2 populations to selection for DT were characterized with SSR markers. χ2 tests on frequency deviation at single loci resulted in the discovery of 104 DT haplotypes across the rice genome. Allelic diversity at many DT QTLs from different donors was suggested based on differences in QTL gene action and effects. Linkage disequilibrium analyses revealed the hierarchy of the multilocus structure of DT QTLs – the presence of multiple QTL groups consisting of positively associated DT loci, which were co-regulated in response to selection, including many perfectly associated QTL loops, which lead to, for the first time, the discovery of the high-confidence genetic networks underlying DT in rice. Second, results from progeny testing of the DT ILs under both stress and non-stress conditions indicated that QTLs within association loops acted like single genes with large effects, providing phenotypic evidence for the presence of the DT genetic networks. Third, F2-derived lines selected under severe drought from crosses between unrelated DT ILs were analyzed with SSR markers and progeny tested to verify the identified DT QTLs and genetic networks. Together, the large numbers of loci involved, the allelic diversity at the detected loci and the genetic networks appear to form the genetic basis of DT in rice. Finally, our results demonstrated a highly efficient strategy for developing DT cultivars by QTL pyramiding using the ILs.

P 7.17 - Evaluation and participatory varietal selection of rice lines in rainfed production environment

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A set of 241 rice lines from different molecular breeding and upland screening experiments were evaluated for their performance and plant type under target production environment during 2004-2005 monsoon season. The experiment was laid out in randomized block design with three replication in plots of 2m x 3 rows. The rainfall was above average during this season and there was no drought stress. IR64 root introgression lines 17, 21, 9 and 12 performed well under rainfed conditions and the highest yield of 5264 kg/ha was recorded by NIL # 17. Among the upland lines, PSBRC 9 registered the highest grain yield of 5760 kg ha-1 coupled with earliness. Among the 149 RI lines of IR58821xIR52561 the highest grain yield of 5060 kg ha-1 was recorded by RI line # 34 followed by RI line # 149 (4438 kg ha-1). Breeders habitually develop rice varieties using centralized breeding approach. Recommended varieties produced by this method are popular only in favourable rice production systems but local (farmer preferred) genotypes still dominate in less favourable environments such as rainfed ecosystem. Six short duration rice lines were evaluated under researcher-managed and consultative farmers' participatory trials in 15 villages in the rainfed ecosystem in 2003 and 2004. Farmers selected varieties to their own judgement. Agricultural extension personnel also observed the bottom up approach of PVS.
P 7.18 - Variation in grain yield, carbon isotope discrimination and ash content of wheat lines selected in water-contrasting conditions

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Two groups of M₆ lines derived by mutation from Salamanca S-75 and selected under water contrasting conditions were used to study variation in carbon isotope discrimination ($\Delta$) and ash content (AC) in the grain. There were 50 lines and 10 commercial varieties, including the original variety; 25 lines were selected under water limiting conditions and the other 25 lines were chosen in water favourable conditions. Field trials were sown at Montecillo (M) and Tecamac (T), Mexico in June 23 and June 29, 2001 in rainfed conditions. Precipitation from sowing to maturity was higher at M (297 mm) than T (237 mm). Significant variation among genetic materials was observed for $\Delta$, AC, grain yield (GY), biomass (BM), harvest index (HI), plant height (PH), days at anthesis (DA) and maturity (DM) at T; similarly significant variation for AC, GY, PH, DA and DM was also detected at M. Broad sense heritability across environments for $\Delta$, AC, RG, BM, HI, PH, DA and DM was 0.65, 0.49, 0.44, 0.31, 0.23, 0.44, 0.82 and 0.71, respectively. At the drier site $\Delta$ was positively associated with GY ($r = 0.44, P < 0.01$) and BM ($r = 0.49, P < 0.01$), and negatively with AS ($r = 0.51, P < 0.01$), whereas at the wetter site $\Delta$ was positively related to BM ($r = 0.39, P < 0.01$) only. Generally, the relative indirect selection efficiency for $\Delta$ was greater than AC for all of GY, BM, HI, PH, DA and DM. These results suggest that $\Delta$ should be more efficient than AC to improve grain yield under water limiting conditions.

P 7.19 - Genetics of drought adaptation in Arabidopsis thaliana. QTL analysis carbon isotope ratio, flowering time and gas exchange parameters in a new mapping population.

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Drought stress is ubiquitous, often severe, and an important selective force in the evolution of plant growth, development, and physiology. Despite its importance, we know surprisingly little about natural genetic variation underlying drought adaptation. Our goal is to understand effects of alleles on whole plant physiology, growth, and fitness. Mutant screening and positional cloning in Arabidopsis have suggested many candidate genes, which may play a role in drought adaptation (reviewed by Bray, Ingram and Bartels, Shinozaki). Finding gene products expressed when exposed to drought stress indicates that these loci may be involved in the biochemical pathways which regulate water stress responses and thus helps to elucidate gene function. Identifying the genes involved in the biochemical pathways is a tremendous task, and an important first step in attempting to understand the water relations of plants. In order to take full advantage of these candidate genes, it would be very informative to examine putatively adaptive traits in natural populations. Here we report on genome wide screens for drought adaptation loci using QTL mapping in a new population of recombinant-inbred lines of Arabidopsis thaliana. We report on QTL affecting flowering time, $^{13}$C, and instantaneous gas exchange traits. Our findings document considerable natural genetic variation in whole-plant,drought resistance physiology of Arabidopsis and highlight the value of quantitative genetic approaches for exploring functional relationships regulating physiology. The ultimate goal of this research is to understand why, as well as how, the Arabidopsis genome has evolved functional variation in traits important in drought adaptation.
P 7.20 - Development and screening on drought tolerance of multi-parental introgression lines in rice

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Using a high-yielding CMS restorer line “Zhong 413” as the recurrent parent and more than 100 cultivars as the donors, a large set of introgression lines were developed in rice after more than three backcrosses and more than two selfings. The population had wide range of variance in many traits like heading date, plant height, grain shape, panicle structure, etc. More than 2,000 introgression lines were screened for drought tolerance in Xiangfan, Hubei for two years. A total of 500 lines were selected based on observation of morphological traits (like leaf rolling, leaf desiccation and delay in heading date). These lines were re-evaluated in the dry season in Hainan. Ninety lines showed high-level drought tolerance according the drought tolerant scores, canopy temperature and ability of recovery. They were used as new restorer lines to develop three-line hybrid rice that had promised yield potential. In addition, they will be evaluated again by using a randomized block design with three replications in the water gradient screening facility in Shanghai. At the same time, molecular markers will be engaged to dissect the drought tolerant QTLs.

P 7.21 - Heterotic grouping of Sudanese sorghum (Sorghum bicolor) landraces for developing drought-adapted hybrid varieties

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Sorghum (Sorghum bicolor) is the most important grain crop in the Sudanese economy and diet with 7.1 million ha of cultivated area and a production of 5.2 million tons. However, average yield per unit area is very low (730 kg ha⁻¹) in comparison to the world average (1295 kg ha⁻¹). The only released sorghum hybrid variety is sensitive to drought and the parasitic weed Striga hermonthica. Therefore, the aim of this study was to characterize the pattern of genetic diversity in a representative samples of adapted Sudanese sorghum landraces (LRs) and to establish genetically distinct pools as base materials for hybrid breeding. Seed samples of 48 LRs from across Sudan were provided by ARC. For comparison, a world-wide collection of 25 inbred lines were included. A total of 31 Simple Sequence Repeat (SSR) markers were employed to establish clusters of potentially heterotic groups. A UPGMA-dendrogram was generated from distance-matrix data using modified Roger’s distance. Results show that LRs are highly variable providing abundant diversity for selection. SSR-clustering revealed distinct LR groups which are considered as promising materials for building up heterotic gene pools as base populations for the development of high-yielding drought-tolerant hybrid varieties. Individuals from different gene pools were crossed in a diallel manner, and all landraces and inbred lines were testcrossed with two cms-lines. All generated materials will be evaluated in regular yield trials at three sites in Sudan in 2005 and 2007. Final clustering will be based on molecular markers as well as field data.
P 7.22 - Effects of drought on combining ability in maize

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Inheritance of important traits within a set of genotypes and heterosis are modified by the interactions between genotype and environment in cultivation. This experiment was conducted with the objective to examine the combining abilities and their interaction with environments in single cross hybrids, produced from ten yellow and eight white selected maize inbred lines in full diallel cross scheme. 90 yellow and 56 white single cross hybrids along with checks were evaluated at two locations (i.e. Khumaltar, altitude 1360 m, summer rainy season and Parwanipur, altitude 115 m, winter and dry season), Nepal, during the 2003-2004 seasons. Most of the tested genotypes produced more than 10-ton yield, significantly better than the best check varieties. Grain yield of tested hybrids showed highly significant (P < 0.01) results for G x E interaction. Yield components like 1000-grain weight, ear to plant ratio, grain rows and grain per ear were also showed significant (P < 0.05) results. The specific combining ability analysis of diallel data showed highly significant (P < 0.01) effects of environments on yield and 1000-grain weight interaction. There was extensive genetic variability among tested hybrids at both locations for the yield and yield components however, genotype x environment interaction showed non-significant results, therefore non-additive gene effects were found to be more significant than the additive gene effects. Yield and yield component was affected by the unfavorable weather conditions, despite that, yellow inbred line, KYM 33, 79, 81 and white inbred line KWM 5, 12, 30, 44 were positive at both location for GCA to yield and potentially superior for drought.

P 7.23 - Genotypic variation for carbon isotope discrimination in sugar beet

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Varieties with increased water use efficiency (WUE), indirectly measured by Delta, could save water while maintaining yield. However, WUE has not been studied extensively in sugar beet. The objectives of this study are: 1) to evaluate genotypic variation for Delta, WUE and dry matter accumulation in sugar beet under well-watered and water-limited conditions; 2) to test the relationship of Delta with WUE, yield and secondary traits, and 3) to identify possible surrogate measures of Delta. Sugar beet genotypes were evaluated in the field where drought stress was imposed by using large polythene covers. There was genotypic variation for root yield, total dry matter (TDM), specific leaf weight (SLW), succulence index, Delta and WUE. Variation in WUE was mainly accounted for by variation in TDM rather than by variation in water use. Delta in leaf and root samples were significantly correlated (r = 0.90, p < 0.05). Delta values in leaves were positively correlated in well-watered and water-limited conditions (r = 0.77, p < 0.01). Leaf thickness indicated by SLW was significantly correlated with Delta (r = -0.78, p < 0.01). The expected negative relationship between Delta and WUE was observed, although it was not significant. Poor correlation between Delta and yield indicates opportunities to simultaneously improve both yield and Delta through hybridization. The results show that leaf samples analysed for Delta under well-watered treatment may sufficiently differentiate sugar beet genotypes for Delta, which has a potential to be used as a selection tool for breeding WUE in sugar beet. However, the establishment of this relationship needs further work with more genotypes.
Rice crop facing moisture stress around flowering stage is often rendered fruitless in totality. Breeding rice varieties with post flowering moisture stress tolerance is attempted. A traditional indica landrace, Norungan which has been under long term adaptation in the target production environment was utilized as the donor parent. Hybridization of Norungan with IR 64 and IR 50 delivered breeding populations comprising Recombinant Inbred Lines (RILs) and Backcross Inbred Lines (BILs) through reciprocal crosses. From a total of 640 RILs and BILs, a subset of 300 lines selected based on their agronomic suitability such as non-lodging medium tall to semi-dwarf habit, photo-insensitivity and moderate to high yield potential were tested in three locations viz., Coimbatore, Paramakudi and Ramanathapuram under on-season. The three environments offered three different testing conditions and the performance of the cultures was evaluated and the interaction components analyzed. A set of 93 RILs selected based on phenology similarity was evaluated as delayed on-season experiment in two contrasting water regimes and the relationship among the component traits and drought response indices was worked out. Selective genotyping of the 93 RILs with 24 polymorphic microsatellite markers in the target genomic regions was attempted. The QTL region in chromosome one was strongly associated with several drought tolerance related traits and indicated the usefulness of the markers in the region for pursuing MAS in populations involving the local parent. Large scale germplasm evaluation and population improvement schemes delivered potential lines for drought prone environments which are under multi location field testing as well as participatory varietal evaluation. Results, progress and future strategies will be presented.
P 7.25 - Analysis of genotype by environment interaction in barley (Hordeum vulgare L.) grown in Mediterranean environments

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Barley is a widely adapted crop that is grown in a range of extreme environments and is noted for its tolerance to cold, drought, alkali and salinity. The interaction of the genotype with the environment (GEI) is of primary importance in many aspects of barley research. This is particularly true in the Mediterranean areas, where crop growth is often exposed to large environmental variations. Under these conditions, GEI analysis may be an efficient tool for the selection of genotypes with satisfactory performances in a given range of environments. According to this perspective, our study was carried out under a typical Mediterranean climate to compare the yield performances of 24 barley genotypes across six different environments (location by year combinations) in Sardinia (Italy). The genotypes were from three different groups: Sardinian barley landraces (SBL), improved varieties (VAR) and recombinant inbred lines (RILs) that were obtained from crosses between two pure lines from Sardinian landraces and one improved variety. Additive Main effects and Multiplicative Interactions (AMMI) analysis was used to investigate the major GEI effects. Our results show that: i) environmental and GEI effects were the main causes of variations in the yield levels; ii) genotype performances differed mainly according to their group of origin; and iii) the more stable yield performance across the Sardinian environments was shown by the RIL group, while the VAR group performed well in favourable environments, and the SBL group showed the best performance in adverse environments.

P 7.26 - Drought tolerant rice varieties through conventional breeding

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While the availability of land and water is shrinking, the only possibility of increasing the rice production to feed the ever increasing population is through increased productivity under rainfed ecosystem. This could be achieved through development of high yielding drought tolerant varieties. To develop high yielding varieties, one should understand the genetic make up and gene action controlling the targeted traits and to identify the better combining parents and best hybrid combinations for isolating superior recombinants through combining ability analysis proposed by Griffing (1956). In the present study, 8 x 8 diallel mating design (Method I & Model I) comprising four land races adapted to rainfed ecosystem and four improved cultivars adapted to irrigated ecosystem was adopted to develop 56 hybrids. These hybrids and their parents were evaluated under managed stress conditions and observations were recorded on drought tolerance traits viz., SPAD, canopy temperature, leaf rolling and leaf drying and yield parameters viz., biomass, grain yield and harvest index. The magnitude of GCA (67.9%) was higher than SCA (32.1%) for all the traits studied indicating the predominance of additive gene effects than non additive. Based on the GCA and per se performance, Nootripathu (landrace), IR64 and IR62266 were identified as best combiners for yield, while Norungan and Kalurunadakar as best combiners for drought tolerance traits. Based on the SCA effects, eight cross combinations were selected for further advancement. The implications of these findings on the breeding strategies/methods to develop high yielding drought tolerant rice varieties are discussed.
P 7.27 - Genetic improvement of rice for stabilized yields in drought-prone environments of Eastern India- A multi-disciplinary approach

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The availability of water for growing crop plants is reducing day-by-day. This has become a matter of concern to the farmers the world over. Rice, which has been pivotal to all aspects of human activities throughout history, is facing this challenge much more than any other crop. The uncertain dry spells of various durations during crop seasons have forced scientists to find ways and means to stabilize rice yield levels including breeding of genotypes with better drought tolerance at various growth stages. Widawsky and O’Toole (1990) estimated the annual losses due to vegetative and reproductive stage droughts to be around US$ 580 m in Eastern India alone. Although, among currently available semi-dwarf varieties a few possessing drought tolerance do exist, most of these are spill-overs of irrigated programs rather than bred systematically. The current approach followed at Indira Gandhi Agricultural University, Raipur includes: (i) Identification of donors for tolerance to drought at vegetative and reproductive stages. (ii) Associating morphological/physiological parameters with such tolerance in each donor. (iii) Utilizing established mapping populations to identify QTLs involved and assessing their stability across environments. (iv) Developing through sustained efforts a local mapping population to identify QTLs imparting local specific tolerance and thus identifying additional QTLs. (v) Developing breeding populations through hybridization among carefully selected parents. (vi) Screening of segregating populations utilizing already standardized field screening protocol. (vii) Multi-location testing involving farmers’ participatory selections. Progress made during the last four years on each of the above aspects has been discussed and data presented. The lessons learnt have been interpreted to modify the experimentation approaches to be followed here onwards.

P 7.28 - Characterization of a core collection of sorghum core collection under 3 water regimes

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Drought is one of the largest factors limiting yield of sorghum in semi-arid areas like in Senegal. With the improvement of farming techniques, identification and/or creation of varieties better adapted to drought could increase sorghum production in drought prone areas. Plant material used in selection and research programs, is usually from local provenance and has a low genetic diversity and limited performances under drought conditions. Thus, these work aim at evaluate agro-morphological characteristics of a core collection of 210 accessions issued from the world collection maintained at ICRISAT-Patechuru, under three water regimes and screen varieties with contrasted responses to drought stress. Three experiments were conducted; one under non-limiting watering conditions (ETM), one with a water stress applied at pre-flowering stage (STRpre) and one with a stress at post-flowering stage (STRpost). Results show that, under any water regime, the core collection exhibits a large diversity of response, according to its genetic diversity. The core collection performs differently according to the water conditions. Indeed, production is nondependent of the vegetative growth parameters in ETM as well as in STRpre, but depends on them in the case of STRpost. Varieties presenting important difference of response from one stress treatment to the control were noted drought sensitive, while those presenting a stability of their parameters from stress to control were classified as adapted to drought.
In rainfed upland rice a deep root system is associated with improved performance under drought. QTL for root length and thickness were previously mapped in Azucena (Az) x Bala recombinant inbred lines. We have used marker-assisted backcrossing (MABC) to introgress four Az root QTL (segments of chromosomes 2, 7, 9 and 11) into Kalinga III (KIII), a variety not used in mapping these traits. KIII is popular with farmers in the rainfed uplands of eastern India but it is susceptible to early season drought. Progeny of BC2 lines carrying each QTL were bulked into six populations, five with one target segment, and one carrying none. All six bulks were segregating for non-target regions of the genome. These were used in participatory plant breeding (client oriented breeding) for selection by farmers in three states of eastern India under upland conditions. The resulting selections were tested on-research stations in three locations under non-irrigated conditions and the results are presented here. BC3 lines carrying introgressed regions for multiple QTL were crossed in order to pyramid the QTL in single genotypes (PY lines). The parent varieties and near-isogenic lines (NILs) with different combinations of QTL were tested for root morphology in soil-filled cylinders in Bangalore under water-stress and fully irrigated treatments. Significant genetic and treatment effects were detected: the QTL on chromosome 9 increased root length, and there was a trend towards longer roots in NILs with more QTL. PY lines were tested in on-farm and on-research station trials and they out-performed Kalinga III.
Panicle exsertion: An important secondary trait determining grain yield under reproductive stage moisture stress

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Drought coinciding with flowering stage is the most detrimental factor in limiting rice production from rainfed regions. When water deficit occurs around flowering period, rice yield is dramatically reduced primarily as a result of spikelet sterility. Slow rate of panicle exsertion might be one of the causes for spikelet sterility. Hence establishing the association of panicle exsertion with grain yield and other component trait of drought tolerance along with identification of QTLs associated with panicle exsertion was attempted. A subset of 93 RILs derived from crosses of IR50 x Norungan and IR64 x Norungan and selected based on their uniformity in flowering, were raised in the field in a delayed on-season. The experiment was conducted in two environments – water stress and irrigated. Panicle exsertion was quantitatively measured by measuring the distance between the collar region of the panicle and the flag leaf juncture in centimeters. A significant variation in panicle exsertion was observed among the parents and the RILs that ranged from -6.8 cm to 6.2 cm. The heritability of the trait was found to be 0.75. Panicle exsertion had highly significant positive correlation with single plant yield (rg = 0.39**), plot yield (rg = 0.24*) and panicle harvest index (rg = 0.38**) and highly significant negative correlation with days to 50% flowering (rg = -0.49**) under stress. Apart from this it had a significant and positive correlation with plant height (rg = 0.69**), panicle length (rg = 0.23*), biological yield (rg = 0.39**), harvest index (rg = 0.24**) and leaf rolling (rg = 0.36**) and a highly significant negative correlation with spikelet sterility (rg = -0.34**) under stress. Difference in panicle exsertion was calculated between stress and irrigated as an estimate of impact on stress on exsertion. It had a significantly negative correlation with harvest index (rg = -0.42**) and single plant yield (rg = -0.22*) under stress while the same exhibited insignificant relationship under control. Similarly the difference in panicle exsertion had a significant positive correlation with Drought Susceptibility Index (DSI) (an estimated parameter for drought susceptibility) which indicated the importance of sustaining panicle exsertion under stress in determining productivity under stress. Selection for secondary trait such as panicle exsertion would naturally help in selecting for genotypes that would yield better under drought. A selective genotyping with microsatellite markers in the target genomic regions reported by Zhang et al. 2001 and Lanceras et al. 2004 revealed three markers, viz., RM246 and RM302 on chromosome 1 and RM149 on chromosome 8 having a strong association with the trait, panicle exsertion under moisture stress condition.
P 7.31 - Early generation screening for yield and secondary traits associated with drought tolerance in rice (Oryza sativa L.)

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Drought adversely affects rice production. Growing evidence indicates that varieties can be developed for improved yield under stress, if there is early selection for yield and drought tolerance. Clear understanding of the variability parameters viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h²) and genetic advance (GA) of the segregating material is essential for further exploitation. Thus in the present study, twelve F₂ population(s) were selected based on combining ability studies of 8 x 8 diallel mating system involving four land races and four improved rice cultivars. These populations were evaluated under imposed moisture stress during reproductive phase in order to identify the segregants endowed with high grain yield under stress for further advancement and to eliminate the unproductive progenies from the breeding cycle in the early generation itself. Data on physio-morphological traits viz., days to flowering, plant height, tillers plant⁻¹, productive tillers plant⁻¹, grains panicle⁻¹, sterility percent, 100-grain weight, biomass plant⁻¹, grain yield plant⁻¹, harvest index, relative water content, SPAD value, leaf rolling and leaf drying were recorded. High phenotypic variation was observed for all the traits studied. The data were subjected to analysis of coefficient of variations, heritability and genetic advance. The analyses of skewness, kurtosis and regression analysis were employed to identify desirable segregants for further advancement.

P 7.32 - QTL analysis of water use efficiency

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Water use efficiency is an important target for breeders in drought prone environments in order to save water resources. However direct evaluation of this trait is difficult. Carbon isotope discrimination (CID) has been proposed for several years as an index of water-use efficiency at the leaf level. The genetic dissection of this trait and other relevant parameters for water-use efficiency has been initiated in rice, within a NSF program; through a QTL analysis and fine mapping strategy. We report here QTL results on two segregating populations from the cross IR64xAzucena for carbon isotope discrimination, leaf morphological parameters, gas exchange data, stomatal conductance and leaf ABA concentrations, in greenhouse experiments. Globally, CID was correlated negatively with leaf width and plant height, and positively with leaf curling. Three significant QTLs have been identified for CID, two of them being antagonists on chromosome 4, and one other located on chromosome 5. The near-centromeric region of chromosome 4 presents a cluster of QTLs for CID, photosynthesis rate and stomatal conductance, supporting the involvement of carbon assimilation and stomatal conductance in the genetic variation of carbon isotope discrimination at this particular locus. However, the two other QTLs (on chromosome 4 long arm and on chromosome 5) may be rather related to structural variation in plants. Our data are compared with results obtained on other crosses and across cereals, particularly with data obtained previously on a barley recombinant inbred line population Tadmor x ER/APM. Perspectives for a genomic analysis of water-use efficiency are presented.
Breeding approaches and achievements in developing drought tolerant rice cultivars for eastern India

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About 80% of the rice area of eastern India is rainfed and exposed to abiotic stresses such as drought, low soil fertility, flood and stagnant water (Singh and Singh 2000). Even though the region receives heavy rainfall, the yield losses caused by drought at anthesis and seedling stages combined were about double those caused by weeds (Widawsky and O’Toole 1990). Breeding for drought tolerance in rice is a challenging task. However, the monetary losses and social insecurities posed by the ubiquitous abiotic stress warrant making an effort for genetic improvement of drought resistance. Recently at our university more targeted approach has been followed with emphasis on identification of local donors for drought tolerance, developing large breeding populations, improving field screening protocol, to increase the efficiency of selection under well-defined water stress. The major activities under the RF funded project on drought are as follows: A set of 75 lines was tested in wet and dry seasons for three consecutive years under water stress and irrigated conditions. Simultaneously these lines were evaluated in pipe for root traits. A few drought tolerant lines were selected which includes Dagad Deshi, Bakal, Bhataphool, Chapti gurmatia, Safri – 17. Number of breeding populations has been developed using these donors along with widely grown cultivars. Since we had number of crosses, it was observed that among the donors Dagad Deshi & Bhata phool and among the recurrent parent Abhaya and IR 42253 usually generate very good sergeants. The segregating generation is being handled in different ways and screened under defined water stresses. Most of the breeding material is screened under irrigated, terminal stage drought and complete rainfed situations. The field screening protocol has been standardized to some extent to increase the heritability of drought related traits and repeatability of the results. Agronomic adjustments like sowing and transplanting are being delayed by 15 days to increase the probability of exposing test material for terminal drought. Proper selection of field: When the water is drained from the field the depletion of water level is not sometimes even and that impose heterogeneity in the field and the performance of the genotypes becomes unpredictable. Physical (recording the depth of free available water in soil), biological (resistant and susceptible checks) and statistical tools are being used to overcome the problem of within field heterogeneity. Using this protocol in the wet season 2004, which was a normal year considering rainfall; the yield under terminal stage drought and rainfed condition was reduced to 12.2 and 22%, respectively, compared to irrigated situation. The overall breeding strategy is to generate number of breeding populations. We have approximately 80 crosses under different generations. The early segregating generation material is tested under irrigated condition and based on overall performance of cross either the cross is advanced by bulk or pedigree method. Poor crosses are rejected. F4 and F5 single line progeny is usually tested under defined water status (Irrigated, rainfed and terminal stage drought) and selections are made based on overall performance. A positive relationship ($r = 0.43^{**}$) was observed between grain yield under irrigated and rainfed conditions. The overall heritability for yield per se under stress condition is about 0.39. The selected lines are usually tested under multiplication sites. Up to the wet season in 2004, we have about 70 lines from different crosses having desirable features, which will be tested under multi-location sites, including farmers’ fields. Using SSR markers we have started developing genotypic data of one RIL population (Safri-17 X Kranti). This population is an F9 generation. The genotypic data of 29 SSR markers has been developed. The data of ~150 markers will be developed for the identification of QTLs for drought tolerance, and particularly for the identification of candidate genes for various root traits as this population exhibits segregation for these traits.
P 7.34 - Integrating client-oriented breeding and marker-assisted selection in rainfed upland rice

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Terminal-drought is the most serious abiotic stress in the fields of marginal farmers of the rainfed uplands in eastern India. Farmers have not adopted varieties developed through the conventional plant breeding approaches because they lack drought resistance and many of the farmer preferred traits such as high fodder yield and cooking qualities. Farmers thus continue to grow old and unimproved cultivars and obtain low yields. Using on-farm, farmer-oriented approaches to breeding and varietal selection a collaborative plant breeding programme was undertaken by GVT, BAU and CAZS. It has led to the release of two drought-tolerant upland rice varieties (Ashoka 200F and Ashoka 228) in Jharkhand in 2003. This program used unique approaches of ‘clever crosses’, low cross number, high population size and simple methods of phenotypic selection to ameliorate the shortcomings of the most preferred variety, Kalinga III, identified in the PVS process. More varieties developed with this approach are in the advanced stages of testing and being popularised with farmers. A second strategy used backcross marker-assisted selection for root trait QTL to improve drought tolerance. This has led to a number of promising bulks with and without root QTL, pure-breeding lines with single QTL and pyramid lines with multiple QTL. These lines have shown excellent field drought resistance and high performance for yield. Varieties developed through both approaches have excellent grain quality hitherto not available to the upland farmers, and some varieties developed by marker-assisted selection also carry an aroma QTL. Performance of new varieties will be presented. Survey results on the adoption and impact of the new varieties on the livelihoods of farmers and their on-farm varietal diversity in Jharkhand, Orissa and West Bengal will be presented. Bioeconomic models show a substantial longer-term impact on the alleviation of poverty.

P 7.35 - Genetic analysis for the improvement of drought tolerance in TGMS based rice hybrids and cultivars

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Drought is a serious yield-limiting factor in rainfed rice production world over. Genetic improvement of rice for drought tolerance is a key factor in overcoming this problem. The genetics of drought tolerant traits both under managed stress and rainfed conditions was studied. Per se and gca effects revealed GD 99036, GD 98049, Varappukudanchan, TM 97017, PMK 3 and PMK 2 as good combiners for the improvement of yield and drought tolerance. The hybrid, GD 99017/TM 97017 for managed stress and GD 99017/Varappukudanchan for rainfed conditions had parallelism between desirable mean, sca effects and heterosis for drought tolerant traits and yield. Stability analysis identified the hybrids viz., GD 99017/PM 01010, GD 99033/Varappukudanchan and GD 99036/Norungan for general adaptation in both environments. Mega environment analysis disclosed the genotypes, PM 01010, TM 97017, PMK 2, PMK 3 and the hybrid GD 99017/PMK 2 suitable for rainfed conditions. Association analysis between yield and drought tolerant traits under managed stress condition suggested that selection based on spikelet fertility, panicle harvest index, days to attain 70% RWC, root length, root weight and root shoot ratio will be effective in improving yield. The results obtained by evaluating rice genotypes for aerobic condition under moderate stress also supported these findings. Screening of promising rice lines developed from IR 20/Nootripathu RIL population along with land races in PVC pipes showed that two advanced cultures (CPMB ACM 04003 and 04004) possessed desirable root number, root volume and root length.
**P 7.36 - Physiology, genetics and marker-assisted breeding of drought tolerance QTL in pearl millet**

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Pearl millet [Pennisetum glaucum (L.) R. Br.] is the staple cereal of the hottest, driest areas of the tropics and subtropics. Drought stress is a regular occurrence in these regions, making breeding for drought tolerance one of the most essential objectives in pearl millet breeding programmes. To facilitate such breeding, we have mapped several QTLs that contribute to increased drought tolerance in pearl millet in two separate populations (Yadav et al. 2002, 2004). In particular we identified a region on linkage group 2 in both populations associated with grain yield and terminal drought tolerance. Physiological and agronomic processes associated with these QTLs were also characterised. These QTLs were then transferred into the genetic background of the respective drought sensitive parent using marker-assisted back crossing and the effects of the individual QTL re-assessed in a range of water environments and genetic backgrounds. These experiments validated the major QTL on LG2. The application of the identified QTL in breeding for increased drought tolerance will be discussed.


**P 7.37 - Constitutive changes in morpho-physiological traits with recurrent selection for mid-season drought tolerance in maize (Zea mays L.)**

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Drought tolerance in maize (Z. m. L.) is largely determined by the growth pattern and physiological activities that occur around flowering (one week before until two weeks after female flowering). We examined the performance of drought tolerant populations (DTP-white and yellow) for adaptive changes associated with tolerance to mid-season drought. Lowland tropical high yielding single cross hybrids and top-crosses of S3 lines from DTP-white and yellow, improved for nine cycles for drought tolerance using full-sib/ S1-recurrent selection scheme, were evaluated under well-watered and severe drought stress during rain-free winter season at Tlaltizapan, Moralos, Mexico (18°N, 940 m elevation). Improved performance of DTP hybrid progenies under drought was associated with constitutive changes in various morpho-physiological traits at critical stages, i.e., flowering and early grain filling (lag-phase). Increased duration of active leaf area, high water uptake and/or water use efficiency, synchrony at flowering, greater assimilate supply to developing ears, and increased kernel and ear set have been found to be associated with drought tolerance. High relative grain yield of improved germplasm under drought was related to increase in number of effective ears and kernel weight, and reduced anthesis-silking interval under drought, without any yield penalty under well-watered conditions. Our findings suggest that recurrent selection for mid-season drought improved nutrient and water use efficiency, and increased translocation of assimilates towards ear growth and kernel development during flowering and early grain filling stage. The selection resulted in short ASI (< 5 days) and reduced ear abortion, and therefore, improved yield and stability across the stresses and unstressed environments.
To understand the genetic basis of drought tolerance (DT) in rice, 84 BC$_2$F$_2$ introgression lines (ILs) originated from three crosses between two recurrent parents (IR64 and Teqing) and three donors (Bg300, Bg304 and BR11) selected under two types of drought stress (lowland and upland) were investigated using with 90 well-distributed simple repeat sequence (SSR) markers and progeny testing. These ILs were evaluated in a replicated experiment for yield and related traits in 2003 under both drought and normal irrigated conditions, and for sheath blight resistance (SBR). Analyses of the genotypic data uncovered 33 chromosome regions at which the genotypic/allelic frequencies were in significant excess, suggesting their possible associations with DT. Linkage disequilibrium analyses revealed strong non-random associations between or among the unlinked DT QTLs, forming highly and positively associated QTL groups. Progeny testing of the BC$_2$F$_5$ progenies under both stress and non-stress conditions and pairwise comparisons between sister ILs indicated that QTL groups behaved like single QTLs with large effects on several traits related DT. Of the 33 DT QTLs detected, 12 were also associated with SBR, suggesting a 36.4% of genetic overlap between biotic and abiotic stress tolerances in rice resulting from either pleiotropy or genetic hitchhiking. Our results indicated that selective introgression is an efficient way to integrate breeding with genes/QTL discovery. Issues of mapping and interpretation of QTLs affecting target and non-target traits using ILs and molecular markers will be discussed.
P 8.01 - Expression of an ELIP-like Dsp22 gene from Craterostigma plantagineum in Nicotiana tabacum: assessing a strategy to increase water-deficit tolerance in plants

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Water deficit induces osmotic stress upon plants by hindering nutrient availability and triggering photo-oxidative stress due to the inhibition of photosynthetic activity (1). The Dsp22 gene from the resurrection plant Craterostigma plantagineum is expressed preferentially upon desiccation and encodes a 22 kDa chloroplast-localised stress protein (DSP), with high homology to the ELIP (Early Light Induced Protein) family (2). ELIPs are pigment-binding protein components of the thylakoid membrane that accumulate transiently in response to stresses and are thought to protect plastids against light stress (3). Recently, a relation between DSP22 accumulation and photoinhibition caused by desiccation was demonstrated (4). This work aims to express the stress-related gene Dsp22 in the model plant Nicotiana tabacum to investigate how it affects plant tolerance to water deficit situations. Several transgenic lines harboring a CaMV 35S driven Dsp22 gene were generated by Agrobacterium-mediated transformation. Various homozygous transgenic lines were obtained and are being evaluated for Dsp22 expression and protein accumulation. Seeds of transgenic lines and of wild type were germinated on MS media supplemented with 0, 0.25 and 0.50M of mannitol and 0, 0.1, 0.2 and 0.3M of NaCl and germination percentages were assessed. A set of physiological parameters will be evaluated to help understanding the response of transgenic lines to water deficit. The results of this work should indicate the suitability of this strategy to increase water deficit tolerance in plants.

(2) Bartels et al. (1992) EMBO J 8:2771-78  
(3) Adamska (1997) Physiol Plant 100:794-05  

P 8.02 - Evidence for genetic variation in water use efficiency in winter wheat and detection of QTLs for carbon isotope discrimination

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Winter wheat is the most extensive arable crop in the UK grown on about 2 Mha p.a. There is a need to identify traits to ameliorate losses to drought which are in the region of 15% per year. The objectives were to identify key stomatal aperture traits underlying genetic variation in water-use efficiency (measured as either net photosynthesis/transpiration, also called transpiration efficiency, TE; or as plant biomass/transpiration) in winter wheat grown in UK conditions and to search for QTLs associated with this trait. We used a doubled haploid (DH) population of 34 lines derived from a cross between Beaver and Soissons. Transpiration efficiency was assessed using the established inverse relationship between TE and carbon isotope discrimination ($^{13}$C/$^{12}$C, $\Delta$). Two glasshouse experiments (2002/3 and 2003/4) and one field experiment (2002/3) were conducted at the University of Nottingham with and without irrigation. Consistent parental differences were found, with Soissons showing a trend for greater plant biomass/ transpiration in glasshouse data and lower grain $\Delta$ (i.e. higher TE) in field data ($P < 0.001$). Gas-exchange measurements indicated lower mean sub-stomatal internal CO2 concentration for Soissons compared to Beaver ($P < 0.001$) - consistent with higher water-use efficiency for this cultivar. In the field, $\Delta$ was positively correlated with grain yield amongst the 34 DH lines ($r = 0.43$), suggesting a negative trade off between TE and seasonal water use. Preliminary genetic analysis has identified the presence of significant QTLs for $\Delta$ on chromosomes 1B, 3A and 5A. A second field season of phenotyping for $\Delta$ is ongoing with the objective of confirming these putative QTLs.
P 8.03 - Nucleotide diversity and association mapping using candidate genes for drought and salinity resistance in durum wheat

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Linkage disequilibrium (LD) is the non-random association among different polymorphisms. LD mapping potentially enables to determine whether candidate genes are associated with variation in a trait of interest using natural populations (or, anyhow, not originated from a controlled cross). In this way LD mapping relies on many more informative meioses (i.e. all those occurred in the history of the samples) than those contained in a traditional mapping population. Association analysis has the potential to identify a single polymorphism within a gene that is responsible for the phenotypic variation. The aim of this work is the analysis of nucleotide diversity in a set of candidate genes for drought and salinity resistance in durum wheat (Triticum turgidum ssp. durum) that will be used for association mapping. An initial set of 100 genes with known function in Arabidopsis and rice have been chosen. Candidate genes set includes stress-inducible transcription factors belonging to many different classes, including the bZIP, MYB, ERF/AP2 and Zn finger families. Candidate genes are sequenced on a total of 88 lines of durum wheat that will be characterized phenotypically during the project. We will present and discuss results on nucleotide diversity in a large set of genic region and the extent of LD in durum wheat genome. This approach will potentially allow to establish statistically significant associations between nucleotide diversity at the candidate loci and the phenotypic variation for the traits of interest and, thus, to identify the genes responsible for such variation to use in durum wheat breeding programs.

P 8.04 - Mapping of QTLs for drought tolerance in barley at different developmental stages

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Drought is one of the most important abiotic stresses, which causes yield loss of cultivated plants. Determining major QTLs influencing drought tolerance could be helpful for identifying drought tolerant genotypes. The aim of our work reported here was the finding of major QTLs for drought tolerance in barley at different developmental stages. Double haploid (DH) lines of the Oregon Wolfe Barley (OWB) population were screened for drought tolerance. The OWB population is saturated with Expressed Sequence Tags (ESTs), which could be helpful for the understanding of the basic mechanism of drought tolerance (functional mapping). To determine the drought tolerance at germination and at seedling stage, the DH lines were screened after 10 days and 3 weeks, respectively, under control and drought stressed environment. Drought stress was generated by adding 15% polyethylene glycol (PEG) to the growing solution. Drought tolerance testing at mature stage was carried out both in greenhouse and in plastic tunnel, as well. The drought stress was provoked by limited watering, starting 10 days after anthesis (Post Anthesis Drought Tolerance, PADT). In the greenhouse only moderate drought stress was used, while in the plastic house moderate and severe drought stress were induced. Drought tolerance at germination stage was determined based on the reduction on the shoot and root lengths, while at seedling stage the drought stress caused reduction in the shoot dry weights was used. For the mature plants the drought tolerance was calculated from the yield loss caused by the stress. QTL analysis was performed for all investigated characters.
P 8.05 - Genetic responses to progressive drought-stress and rehydration in the leaves and stems of grass pea (Lathyrus sativus L.)

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Grass pea (Lathyrus sativus L.) is a crop of economic significance in countries where extreme environmental conditions prevail (India, Bangladesh, Ethiopia). It shows a number of unique adaptation features, including a high resistance to drought. To date, information regarding the molecular mechanisms of grass pea adaptation to water deficit is extremely scarce. Therefore, we studied the expression patterns of several target genes in Lathyrus plants submitted to a controlled drought-stress followed by rehydration. Two cultivars with different strategies for coping with water deficit were considered. Selection of the target genes was done in accordance with results from previous studies by our group showing their usefulness in assessing the capacity of legume species (cowpea, groundnut) to trigger adaptive cellular autophagy (ACA), a controlled process that allows plant tissues to adapt to water deficit. This group of genes coded for hydrolases and hydrolase inhibitors. In addition, we tested the involvement of a dehydrin in grass pea responses to drought-stress. RT-PCR technology with degenerate primers was used to amplify cDNA fragments corresponding to each of these genes. Oligonucleotides were then designed and used as Lathyrus-specific primers in PCR reactions on leaf and stem tissues to determine genes expression levels. Results showed that: 1) stems played an important part in the preservation of aerial tissue homeostasis; 2) the accepted drought-tolerance of Lathyrus plants could result from an efficient ACA system; 3) differences between cultivars exist at the molecular levels and could be used in plant breeding programmes for improved stress tolerance.

P 8.06 - Improvement of basal root thickness in rice using marker-assisted selection

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Rice is a major staple food for more than 30% of the world’s population with 85% of its production devoted to human consumption (IRRI, 1997). Rice is grown in diverse agro-ecological conditions and nearly half of the areas planted in rice are in rainfed ecosystems. Drought is one of the main abiotic constraints in rice, causing huge yield losses each year. A thick and deep root system is considered a favorable component allowing rice crops to maintain their water status under conditions in which there is water available at deep soil layers (Nguyen et al., 1997). The main objective of this study was to demonstrate the effectiveness of marker-assisted selection (MAS) for improvement of basal root thickness in rice. A major QTL associated with basal root thickness (BRT) and its linked Restriction Fragment Length Polymorphism (RFLP) markers on chromosome 4 (Nguyen et al., 2003), were used as the target for MAS. Near-isogenic lines (NILs) were developed using the backcross (BC) breeding method. Two parental rice lines contrasting in their root characteristics, CT9993-5-10-1-M (CT) and IR62266-42-6-2 (IR), were used in this study. Genome survey of selected lines from the BC3F1 Population showed that the average percentage of the recurrent parent genome of these NILs was 88.525, which is close to the expected value of the BC3 generation (87.5%). Eighteen NILs that carry the target QTL for basal root thickness were selected from the BC4F2 population for root characteristic evaluation. Results from an evaluation of basal root thickness of selected NILs from the BC4F2 generation indicated that plants carrying an introgressed segment from the donor parent (CT9993-5-10-1-M) did have improved basal root thickness. On average, the basal root thickness of the NILs was about 20 to 50% larger than that of the recurrent parent.
We assembled 192 genotypes that represented landraces and older and contemporary cultivars, the majority from the Mediterranean basin and the remainder from the rest of Europe. The genotypes were grown in irrigated and rainfed trial in each of seven Mediterranean countries for harvest 2004. The 192 genotypes were also genotyped with a stratified set of 50 genomic and EST derived molecular markers, with number of alleles detected at each marker locus ranged from 26 (Bmac0399) to 1 (scssr05281 and scind00149) with an average of 8.7 alleles. Given the diverse origins of the germplasm, we expected that there will be some population substructure and we examined this with STRUCTURE. This revealed five sub-groups that corresponded to: 1. Non-Mediterranean European spring genotypes, 2. Non-Mediterranean European winter genotypes, 3. Jordanian genotypes, 4. Turkish genotypes, 5. Mediterranean 6-row genotypes. Yield data was gathered from 13 of the 14 trials harvested in 2004 and REML was used to estimate the yield BLUPs for each trial. AMMI-analysis on the GxE table of BLUPs showed that landraces did relatively well under stress in Syria and Jordan, whereas modern cultivars seemed more adapted to Spanish and Italian conditions. Forward selection was used to identify marker alleles having significant associations with yield, taking into account population substructure as revealed by the Bayesian cluster analysis contained in the program STRUCTURE. This analysis revealed that chromosomes 6H and 7H were frequently detected and therefore likely to be important in the genetic control of yield under stress.

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P 8.08 - Response of transgenic soybean to limited water conditions in the field

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Transgenic soybean containing an Arabidopsis P5CR gene and inducible heat shock promoter was compared under a rain outshelter with untransformed cultivars. Water regimes of 100, 50 and 30% were applied to the plants from flowering stage. A height difference between the transgenic plants and the cultivars occurred during the trial, with the transgenic plants noticeable taller. The transgenic plants also express this with a higher above ground biomass than the cultivars. Brown lesions as a result of heat stress only appeared on the cultivars indicating that the transgenic plants were more heat resistant. Relative water and proline content were determined on the leaves during the stress period. A dramatic increase in proline levels with increasing stress was observed. Chlorophyll fluorescence measurements also indicated differences between the transgenic lines and cultivars, especially with regard to electron transport and dissipated energy flux. Genetic manipulation of soybean to increase the water use efficiency seems possible with the high yield in the transgenic lines under the water restricted conditions. When using relative yield is an indication of the yielding potential of the lines, it was noted that higher values were obtained with the transgenic lines than with the parent, especially at 50% water treatment. The seed weight of the cultivars was lower than that of the transgenic lines. The transgenic plants also proved more drought tolerant than the parent when using drought susceptibility index as quantification of drought tolerance.

P 8.09 - Isolation and characterization of a novel protease inhibitor regulated by drought stress in groundnut (Arachis hypogaea L.)

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Groundnut (Arachis hypogaea L.) is an important subsistence and cash crop in the semi-arid Tropics. In many parts of the world, groundnut is grown under rain-fed conditions. The crop often suffers from drought-stress of varying intensity and duration. However, little is known about the molecular events involved in this crop adaptive responses to drought. To monitor molecular changes in plant tissue submitted to water deficit, an original experimental plant system was developed. It consisted of two groundnut cultivars with different degrees of drought tolerance, as determined from both field and green-house physiological studies. The plants were submitted to controlled drought-stress by withholding irrigation and rehydrated for 24 h. Four water deficit levels (well watered, light stress, moderate and severe stress) were defined according to leaf water potential values, -0.25 MPa, -1.5 MPa, -2.5 MPa, -3.5 MPa, respectively. Gene expression study in the leaf tissues led us to the isolation of a drought-responsive cDNA (Ah-PI-f) using 3'-5' RACE. Ah-PI-f sequence analysis indicated that it was related to protease inhibitors. Expression analyses of Ah-PI-f gene (Real-Time PCR) and AH-PI-F recombinant protein showed that: (1) Ah-PI-f was mostly expressed under moderate water deficit conditions, (2) expression was higher in the drought-tolerant than in the drought-sensitive cultivar, and (3) therefore, Ah-PI-f could be involved in drought tolerance mechanisms at the cellular level. As a conclusion, we propose that Ah-PI-f be used as a molecular tool to help in further development of drought-tolerant groundnut cultivars, by conventional breeding methods and/or by genetic engineering.
P 8.10 - Models of root system architecture on the way to improve the power and informativity of QTL analysis

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Root system architecture (RSA) is an important component of soil water extraction by plants, especially in drought-prone environments. Just as an example, there are a number of instances suggesting that a redistribution of root growth towards deep layers may contribute to sustain agricultural performance under water deficit. The finding of genetic variance for RSA suggest that there is a scope for considering related traits in crop improvement. Until now, however, even with easily tractable reference species like *Arabidopsis thaliana*, most genetic studies of RSA are limited to estimates of root variables (viz. length, diameter) at a single time-point and escape the fact that RSA is but the ultimate expression of several biological processes which operate continuously and simultaneously (e.g. growth, root emission and branching, decay). It seems reasonable to expect that the power of genetic studies, when it comes to RSA, would be greatly enhanced if we were able to work, for example, with elongation rate response functions instead of point length measurements. But then come the inherent problems of root observation and the complexity of RSA, comprised of thousands of meristems. This presentation highlights new possibilities to exploit information contained in point data using models of RSA (typically 4D models, e.g. RootTyp) in order to develop a more dynamic analysis of RSA. The illustrated methodology consists in adjusting a model to point estimates of RSA in a segregating population, then proceeding with the QTL analysis of the set of model parameters for each line (this work is under way).

P 8.11 - Transformation of the model legume Medicago truncatula with Adc gene from Avena sativa to improve drought tolerance

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Polyamines (PAs) are low-molecular weight polycations present in all living organisms. Major polyamine forms are putrescine, spermidine and spermine. In plants, polyamines are involved in developmental processes and stress responses (a). In drought situations PAs may act as osmoprotectants, as scavengers of reactive oxygen species or by stabilizing thylakoid membranes (b). Here we present an approach to improve drought tolerance in *Medicago truncatula* (barrel medic) by transformation with the Adc gene from *Avena sativa*. The Adc gene encodes for arginine decarboxylase, an enzyme involved in the PAs biosynthetic pathway. Using Agrobacterium-mediated transformation we obtained several transgenic lines of *M. truncatula* cv Jemalong harbouring the Adc transgene driven by the CaMV 35S constitutive promoter (c). PAs (putrescine, spermidine and spermine) in transgenic and non-transgenic plants are being quantified using HPLC. Physiological parameters (e.g. chlorophyll fluorescence) will be analyzed to evaluate the contribution of the transgene to drought tolerance.

P 8.12 - Development of drought tolerant rice cultivars by highly efficient QTL pyramiding

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Rice is sensitive to drought at different developmental stages, particularly at the reproductive stage. Because of its genetic complexity, drought tolerance (DT) in rice is difficult to improve through conventional breeding. To solve this problem, we conducted a large marker-assisted QTL pyramiding experiment to develop elite rice lines with significantly improved DT and yield potential for the rainfed areas of South and Southeast Asia. Our objectives are to verify previously identified QTLs in the parental IR64 ILs, to pyramid multiple non-allelic DT QTLs of different origins, and to detect and remove possible genetic drags associated with DT QTLs. Three promising ILs with good yield potential and each having 8 - 17 DT QTLs from two unrelated donors (BR24 and Shwe-Thwe-Yin) were used as the parental lines. Two crosses were made and advanced to F2 generation. The F2 populations were subjected to severe drought and a total of 80 DT plants were selected. The selected F2 plants were genotyped with segregating SSR markers and progeny tested in replicated experiments under both stress and non-stress conditions. Analyses of allelic and genotypic frequencies indicated that the donor alleles at all DT QTLs were in excess in the selected F2 progeny. Linkage disequilibrium analyses indicated that approximately 50% of the unlinked QTLs formed a strongly and positive associated group and others acted largely independently. Results from the progeny testing indicated that the yield performance under stress was largely determined by the QTL group plus a few QTL of large effect. Some promising lines with significantly improved DT and yield potential were developed, which will be released to rice farmers in the rainfed areas of South and Southeast Asia.

P 8.13 - Association mapping of stay-green in sorghum

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Abstract: Sorghum [Sorghum bicolor (L.) Moench] is the fifth most important cereal crop globally after wheat, maize, rice and barley. After soil nutrient deficiencies, drought stress is the most important abiotic constraint to sorghum production globally. Stay-green (delayed leaf senescence) is the best-characterized component of post-flowering (i.e. terminal) drought tolerance available in sorghum and is associated with both resistance to charcoal stalk rot and superior ruminant nutritional quality of grain crop residues. Breeding line B35 is the best-characterized source of the stay-green component of terminal drought tolerance in this crop, and QTL for this trait from the B35 source have been mapped repeatedly. Other mapped sources of stay-green are E36-1 and SC56. Associations between 206 alleles generated with 34 SSR markers and this complex quantitative trait [measured as percent green leaf area (GLA) evaluated at 15, 30 and 45 days after flowering based on weekly field observations over two years on crops subjected to post-flowering stress] were investigated in a collection of 69 diverse sorghum genotypes. Significant associations (P < 0.0005) were observed between five alleles and GLA 15, 30 and 45, between seven alleles and GLA 30 and 45, between five alleles and GLA 45, and between one allele and GLA 15 and 30. A number of the alleles associated with GLA were located in genomic regions where B35 and E36-1 stay-green QTL have been mapped previously, thus confirming the importance of these regions for the stay-green phenotype. These associations need to be confirmed after properly accounting for inherent genetic structure.
**P 8.14 - Molecular mapping of drought tolerance traits in maize**

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Aim of this work was the identification, in maize genotypes adapted to temperate areas, of genomic segments responsible for the expression of drought tolerance of nine traits representing main yield and development components. A linkage analysis between the expression of these traits and molecular markers was performed on a recombinant inbred population derived from the cross between H99 and B73, genotyped by 156 RFLP and SSR markers. The population was evaluated in well-watered and two water-stress conditions: intermediate and severe. A drought tolerance index was calculated as the ratio between the mean value of the traits in stress and control conditions. With the aim of detecting QTLs involved in a global response to drought, all data were subjected to both univariate and multivariate analysis, by which numerous QTLs were detected. In several cases the chromosomal regions carrying putative factors for the different traits were the same in control and under both weak and severe stress, while QTLs associated with tolerance indexes were generally different, suggesting that drought tolerance for yield and development components is often associated with genetic and physiological factors independent from those determining the traits per se. Finally, the results from univariate and multivariate analysis were usually congruent, and in some cases the latter allowed to reduce the number of significant QTLs able to explain the concomitant variation of more traits.

**P 8.15 - Selective introgression, detection and verification of QTLs for drought tolerance of rice**

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In the past seven years, we have developed large numbers of drought tolerant (DT) introgression lines (ILs) in three elite genetic backgrounds in a large BC breeding program. To trace the donor genomic segments in the ILs that were responsive to selection and thus presumably associated with DT, ILs selected under two types of stresses (lowland and upland drought) from crosses between two recipients, IR64 and Teqing, and three donors (FR13A, OM1723 and Type3) were characterized with well distributed SSR markers and progeny tested in replicated experiments under irrigated and drought conditions. X² tests revealed a total of 76 non-redundant loci at which donor allele and/or genotypic frequencies deviated significantly (P < 0.005) from the expectations, suggesting possible harboring of DT genes in these regions. On average, DT loci detected in the ILs selected under the lowland and upland conditions and across different populations showed significant levels of genetic overlap. Pairwise linkage disequilibrium (LD) analyses uncovered pronounced non-random associations between or among DT loci, including nine association loops each consisting of multiple unlinked but positively and virtually perfectly associated loci, which allowed us to construct the genetic networks underlying DT in rice. Detailed analyses of the data from the progeny testing indicated that unlinked loci in each of the association loops acted like single QTLs with significant effects on one or more phenotypes. Some QTLs with large effects were verified by comparisons between near isogenic ILs. Based on the phenotypic effects, the possible mechanisms of some DT QTLs or QTL loops are discussed.
P 8.16 - Pyramiding of quantitative trait loci (QTL) controlling root-related traits in rice (Oryza sativa L.)

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The decline in availability of irrigation water in traditional rice belts has forced rice cultivation into regions, limiting in fertility and water supply, necessitating breeding for genotypes to combat such situations. Roots play a major role in addressing drought as they are responsible for uptake of water from deeper soil layers during adverse situations. In this study, a set of twenty-nine near isogenic lines of IR64 introgressed with four regions on chromosomes 1, 2, 7 and 9 from Azucena, known to harbour QTLs that confer drought resistance through control of root morphological traits were used to develop pyramids in combinations of 2, 3 and 4. They were subsequently evaluated for roots morphological traits in pipes and for plant and yield traits in field. Stress was imposed at the onset of reproductive phase for a period of ten days to ascertain the contribution of QTLs towards drought resistance. Database search of the DNA sequences of QTL regions elucidated candidate genes underlying the root QTLs performance during stress. The results indicate a non-significant increase in the pyramids for root traits over their NIL parents in some combinations. The seed yield was higher than IR64. Important genes identified in the QTL regions are CBFs, MYB transcription factors, bZIP transcription factors, TPS, P5CS, expansins, dehydrins, protein kinases, SAM synthetase, auxin responsive proteins, 14-3-3 proteins, osmotins and water stress induced WS118 proteins. Some genes are unique to certain QTL regions, while some are present in more than one QTL regions. More specific analyses to confirm the extent and type of epistasis operant are being conducted.

P 8.17 - Study of drought stress on some morphological, physiological characteristics and antioxidative enzymes activity levels in different genotypes forage sorghum

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In order to investigate the role of antioxidant enzymes superoxide dismutase (SOD), catalas (CAT), and glutathion peroxidase (GPX) in the drought resistance of forage sorghum varieties, an experiment was carried out under drought and control conditions. A split plot design experiment using randomized complete block with three replication was used, so that irrigation treatment was considered the as main plots and varieties forage sorgham as sub plots.No significant difference was found among the varieties at the level of these enzymes.But significant difference were observed among the dry matter, number spike in m², number of leaf in plant, leaf electrical conductivity, width leaf and length leaf in all the genotypes.the results also indicated that drought stress dosnot affect different activity levels of enzymes. Therefor selection for drought resistance by evaluation of SOD, GPX and CAT in these varieties is not useful.
Drought is the major abiotic constraint by now known to be controlled by QTLs. Rainfed rice growing area under upland constitute to more than 48% of total rice area in India and the stage of crop suffering from drought varies based on the rainfall pattern and distribution is prone to vegetative and/or reproductive stress. There exists genotypic variation for stages. QTL introgressed lines from upland rice and, land races of rice locally adapted serve as excellent sources for drought tolerant genes. Some of the QTL are effective in vegetative stress and some at reproductive stage. Genotypes respond differentially at different stages within the reproductive phase. It was possible to identify the most critical period for grain filling under stress by carrying out experiments by compartmenting the reproductive phase. Since drought is a complex trait and QTLs act in combinations, pyramiding the QTL help in detecting the magnitude contributing to tolerance. They also exhibit the weightage of QTLs in effectively contributing to drought. It is possible that one robust QTL can significantly contribute and some in combinations. We also investigated the possibilities of saving water maintaining productivity by using land races, local rices and the upland QTL introgressed lines. By direct seeding and providing irrigation water once in 7-10 days during the wet season, it was possible to save up to 50% water. It was possible to identify genotypes that can have higher productivity under aerobic conditions in sandy loam soils.
Overexpression of the DREB1/ CBF gene family improved stress tolerance to drought, high salt and low temperature in rice

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Plant productivity is greatly affected by environmental stresses such as drought, high salt and low temperature. A cis-acting promoter element DRE/CRT plays an important role in regulating gene expression in response to these environmental stresses. Arabidopsis transcription factors DREB1s/CBFs bind to DRE and control expression of many stress-responsive genes. In rice, we have isolated cDNAs for DREB1 homologs and named them OsDREB1s. We have reported previously that overexpression of the DREB1 or OsDREB1 genes induced strong expression of the many stress-responsive genes in transgenic Arabidopsis plants, which in turn increased stress tolerance to high salt and freezing. In this study, we produced transgenic rice plants overexpressing the DREB1 or OsDREB1 genes. These transgenic plants showed improved tolerance to drought, high-salt and low-temperature stresses like the transgenic Arabidopsis plants overexpressing DREB1 or OsDREB1. We also detected elevated content of a free proline and various soluble sugars in the transgenic rice like the transgenic Arabidopsis plants. We selected candidates as target genes of OsDREB1A in rice by microarray analysis and these genes were confirmed by northern blot analysis. These results indicate that the DREB1 gene family is quite useful for improvement of stress tolerance to environmental stresses in various kinds of transgenic plants including rice. However, these transgenic plants showed growth retardation under normal growth condition. To minimize this negative effect on the plant growth, we generated transgenic rice overexpressing DREB1 genes driven by a stress-inducible promoter.

Molecular approaches for developing drought tolerant crops in JIRCAS

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Molecular studies have shown that several genes with various functions are induced by environmental stresses such as drought, high-salinity and low temperature in plants. Most of the dehydration responsive genes are induced by the plant hormone abscisic acid (ABA), but others are not. Expression analyses of dehydration-responsive genes have provided at least four independent regulatory systems (regulons) for gene expression in a model plant Arabidopsis thaliana. The cis-acting elements in the promoters of some genes that have a typical stress-inducible expression profile and the transcription factors that affect the expression of these genes have been analyzed. Transcription factors that bind to a DRE/CRT (dehydration-responsive element / C-repeat) cis-acting element were isolated and termed DREB1/ CBF (DRE-binding protein 1/ C-repeat binding factor) and DREB2 (DRE-binding protein 2). Overexpression of DREB1/ CBF in transgenic Arabidopsis plants increased tolerance to freezing, drought and high salt concentrations. The DREB1/ CBF genes have been successfully used to improve abiotic stress tolerance in a number of different crop plants. Studies on the other transcription factors associated with stress response are in progress. We are collaborating with many international research institutes to develop stress tolerant crop plants utilizing regulon biotechnology. We hope the results of these collaborative research activities will contribute to the sustainable food production in developing countries and help to prevent the global-scale environmental damage.
P 8.21 - Transgenic sweet potato and potato plants with enhanced tolerance to multiple environmental stresses

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Oxidative stress derived from reactive oxygen species (ROS) is one of the major damaging factors in plants exposed to environmental stress. In order to develop transgenic sweet potato (Ipomoea batatas L. Lam cv. Yulmi) and potato (Solanum tuberosum L. cv. Atlantic and Superior) plants with enhanced tolerance to multiple stress, the genes of both Cu/Zn superoxide dismutase and ascorbate peroxidase were expressed in chloroplasts under the control of an oxidative stress-inducible peroxidase (SWPA2) promoter (referred to SSA plants). SSA sweet potato and potato plants showed enhanced tolerance to oxidative stress caused by the application of methyl viologen (MV, paraquat), a ROS-generating non-selective herbicide. SSA sweet potato plants showed higher tolerance to chilling stress than non-transgenic (NT) plants, whereas SSA potato plants showed higher tolerance to high temperature. SSA sweet potato plants showed a strong tolerance to the application of sulphur dioxide (500 ppb), NT sweet potato plants showed more rapid reduction in Fv/Fm indicating maximum photochemical efficiency of PS II compared with SSA plants on the level of detached leaves, indicating that SSA plants are tolerant to water stress. Further characterization of SSA plants is under investigation in terms of multiple environmental stress on the level of whole plants. Our results strongly suggested that the rational manipulation of antioxidative mechanism in chloroplasts will be applicable to the development of all plant species with enhanced tolerance to multiple environmental stress to contribute in solving the global food and environmental problems in the 21st century.

P 8.22 - Molecular, cytological and phenotypic study of the reciprocal translocation present in the barley variety Albacete

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Albacete is a six-row barley variety adapted to low-yielding western Mediterranean areas. So far, it has been grown in Spain for up to 1 million ha/year since 1955. It carries a reciprocal chromosomic translocation. Although many artificially-induced translocations are available in barley, this is the only known case of a large translocation in a widely cultivated genotype. It is not known whether or not this chromosomal rearrangement is implicated in its good adaptation to drought and if these potential effects can be inherited by other genotypes. Genes in a translocation are locked together and genetic recombination seldom takes place. This fact is of particular interest to identify QTLs, which could be then easily transferred to other genotypes. A total of 118 Albacete x Plaisant double haploids lines (DHL) were studied to identify the chromosomes involved in this interchange. Transmission of the translocation was shown by the presence of tetravalents in the meiosis of some of these DHL backcrossed with Plaisant. The chromosomal arms involved in the translocation have been revealed by FISH (Fluorescence In Situ Hybridization). At the same time, we have established a preliminary map of this cross using eighty polymorphic markers, microsatellites and EST, of known position within the barley genome. Available cytological and genetic data suggest that the translocation present in Albacete affects the short arms of chromosomes 1H and 3H. We have started this year the study of the phenotypic effects associated to this translocation, particularly its potential relation to adaptation to semiarid conditions.
P 8.23 - Association of microsatellites (SSR) and morpho-physiological traits with yield in durum wheat under abiotic stresses

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Durum wheat is grown in the dryland of the Mediterranean region under stressful and variable environmental conditions. This study discusses under an agroecological viewpoint, how to determine or select the traits which enable us to characterize in the case of durum wheat the genotypic differences in grain yield under Mediterranean conditions. The study approaches other aspects related to the utilization environmental of marker microsatellites (SSR) in the selection for drought tolerance, and their associates to physiological mechanisms under environmental constraints of morpho-physiological traits. The association of the microsatellites with various morpho-physiological traits, in particular with grain yield are discussed and studied on a population of 95 lines of durum wheat generated from a cross between Zenati-Bouteille (low yielding) and Waha (high and stable yielding). The population and its parents were tested at ICARDA durum program in Syria, in diverse moisture regime environments. In a multiple regression analysis, it has been demonstrated a variation and an important significant association of marker microsatellites and morphophysiological traits with gain yield. The evaluation of the plant growth is made using the technique of teledetection based on spectral radiometry. These indices present a strong association with grain yield and the microsatellites (GWM66, GWM155, GWM156). Also associations are observed between grain yield and fluorescence, photochemical quenching, total chlorophyll with (GWM66 and GWM 58). The phenological parameters and that which determine the plant water status (stomatol conductance, relative water content, transpiration, and the canopy temperature) are related with grain yield in different environments and also with the microsatellites, (GWM156,GWM66,GWM340). The results demonstrate the effectiveness of (SSR) in genetic studies of complex traits at the population, and they indicate that the SSR markers can be use of practical for durum wheat selection.

P 8.24 - Mechanisms of drought resistance in near-isogenic lines of cotton

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Low water availability is among the major causes for crop yield reductions affecting the majority of the farmed regions around the world. Thus, learning about the mechanisms of plant drought resistance is necessary to improve crop performance under stress. In previous study in our lab QTLs for productivity under arid conditions, and related physiology traits were mapped in inter-specific cotton (Gossypium barbadence x G. hirsutum) populations. The role of major QTLs associated with drought resistance is targeted in the current study. Near Isogenic Lines (NILs) for selected genomic regions, containing QTLs associated with improved productivity, water-use efficiency and osmotic adjustment, where developed. QTLs were mutually introgressed into the parental line that lacked the favorable allele. NILs are being tested in the field under well-watered (control) and water-limited irrigation treatments. Phenotypic characterization include plant productivity (in terms of total dry matter and seed cotton yield), carbon isotope ratio (an indicator of water-use efficiency), osmotic adjustment, chlorophyll content, canopy temperature and gas exchange.
Marker-assisted selection for QTL of basal root thickness in upland and lowland japonica rice

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Root traits are key components of plant adaptation to drought environment. A previously identified quantitative trait locus (QTL) conferring thicker basal root thickness (BRT), located on chromosome 4, designated brt4.1, were chosen as target QTL to study the MAS effects for traits related to rice drought resistance. Three segregating populations, derived from crosses between a japonica upland rice variety with drought resistance and high yield potential and two japonica lowland rice varieties with better grain quality and sensitive to drought, were used in this study. The results showed that flanking markers of brt4.1 (RM1136-RM273) were genetically stable in different populations, with different genetic backgrounds. In the two populations under upland conditions, the differences between the means of BRT of individuals carrying and not carrying favorable alleles at brt4.1 flanking markers loci were significant at 1% level by t test. The results also revealed that selection with flanking markers of brt4.1 could not obtain the expected QTL effect in one population under lowland conditions. Some individuals, selecting from individuals with favorable alleles at brt4.1 flanking markers loci randomly, were used to track the MAS effects for different generations based on genotypes. The results showed that many traits related to drought tolerance, besides BRT, were much exceeded the control in different generations (BC 1F2, BC1F3, F3, F4), under different (Beijing, Hainan) upland conditions. All these results revealed that BRT played an important role in rice drought tolerance breeding and confirmed the effectiveness of MAS based on QTL flanking markers.

A transgenic approach with transcription factors to address abiotic stress tolerance in rice (Oryza sativa L.)

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Agricultural productivity is severely affected by abiotic stress. Transcription factors have been shown to play key roles regulating tolerance to a range of abiotic stresses, including drought, cold and salinity. In order to improve rice tolerance to these adverse environmental conditions we have been using a transgenic approach. As a first strategy, rice (Oryza sativa, cv. Nipponbare) is being transformed with homologous or heterologous (from barley) transcription factor genes related to abiotic stress tolerance, under the control of different promoters, such as the maize ubiquitin promoter or the stress inducible rd29A promoter. Transformed and regenerated rice plants carrying and expressing transgenes for abiotic stress tolerance will be further analysed. This analysis will focus on phenotypic, biochemical (mainly oxidative stress pathway) physiological and molecular characterization of the transgenic lines to select the ones with improved stress tolerance. Several abiotic stress induced-genes will be used as molecular markers for stress tolerance. In addition, we are isolating transcription factors that interact with promoters of genes involved in abiotic stress response using the Yeast one-hybrid system. After validate the interaction with the respective promoter, these transcription factors will be either over-expressed or silenced (RNAi) in rice under the control of a constitutive promoter. This procedure will unravel both whether these TFs act as activators or repressors of the abiotic stress responsive genes and their putative function in developmental processes.
IDuWUE: an EU-funded project for the improvement of water-use efficiency and yield stability in durum wheat


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Durum wheat is mainly grown in drought-prone areas. Improving water-use efficiency thus represents a major breeding goal. IDuWUE (Improving Durum wheat for Water Use Efficiency and yield stability through physiological and molecular approaches) is a collaborative project among Research Centres from Italy, Spain and WANA (West Asia and North Africa) countries (Morocco, Tunisia, Syria and Lebanon) funded by the European Union aimed at investigating the genetic variation for water-use efficiency (WUE) and yield stability in durum wheat genotypes grown in the Mediterranean drought-prone areas. A number of morpho-physiological traits (e.g. early vigor, flowering time, leaf rolling, number of fertile tillers, etc.), WUE, WUE-related traits (e.g. carbon isotope discrimination, canopy temperature, chlorophyll fluorescence, etc.), yield and its components are being investigated on a RIL population (249 lines) and a collection of ca. 190 durum wheat accessions during the first year of the project (2004) in field trials carried out under irrigated and rainfed conditions. The results of the QTL analysis carried out on the mapping population will be integrated with an LD association study performed on the collection of accessions; in this respect, the population structure has been preliminarily estimated with AFLPs and will be further investigated with SSRs. The molecular and phenotypic results so far obtained will be presented and discussed.

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P 8.28 - Variation for yield components in a durum wheat recombinant inbred line population under water-limited conditions

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In durum wheat drought is one of the major factors limiting grain production in the Mediterranean countries. The plant’s response to water stress depends on its metabolic activity, morphology and stage of growth. The risk of drought is highest during the filling period in which water stress often occurs with high temperature stress. Durum wheat breeders attempt to select genotypes that perform well or are stable across environments, including non stress and stress environments. However this does not always seem to be possible, especially for yield. Identifying QTLs that show consistency in expression across environments, even diverse environments, would be desirable for a marker assisted selection regime. In the experiment reported here, trials with a recombinant inbred line (RIL) population, derived by single seed descent from the cross between the cvs Svevo and Ciccio, were conducted in the field under watered and rainfall conditions, respectively. Several yield components (grain yield, ear number, kernel number, 1000 kernel weight, grain yield per spike, hectolitre weight) and plant adaptive traits (heading time, plant height) were measured. Correlation analysis of these traits showed that most of them were not independent of each other. Drought resulted in a significant decrease of grain yield and yield components under stress conditions. The RIL population is being analyzed by molecular markers to identify the genomic segments responsible for the expression of yield components with the final aim of developing marker-assisted selection strategies.

P 8.29 - Identification and evaluation of near-isogenic lines for Silicon uptake in a japonica x indica mapping population of rice (Oryza sativa L.)

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Drought resistance is a complex trait depends on action and interaction of different morphological, physiological, phenological and biochemical characters. Higher silicon content in rice increases photosynthesis, enhances strength of tissues and reduces transpiration of plants, resulting in increased resistance of plants to physical, chemical and biological stresses such as water deficiency, radiation damage, nutritional imbalances, metal toxicity, diseases and pests. Genetic dissection of such complex traits can be done using near isogenic lines (NILs). NILs have been widely used by plant breeders in the development of varieties as well as for mapping various traits. NILs serves as invaluable material for developing mapping population, isolating genes for cloning and use in transformation experiments. They help to identify and map desired genes more rapidly as compared to varieties with different genetic backgrounds. We have developed and tested a strategy for marker-assisted identification of NILs for silicon uptake with the help of 315 marker data on 154 Double haploid population of CT9993/IR62266, we identified genotypes with differences ranging from four (1.27 %) to 34 (10.48 %). These genotypes were phenotyped in replicated experiments under contrast moisture regimes. Silicon content in grains, leaves and stem were estimated. Statistical analysis of data using clusters based phenotypic data of moisture regimes and correlations revealed pairs differed from zero to seven traits under well watered and from zero to six traits under stress.
P 8.30 - Adaptation of wheat to water-limited environments in northern Australia

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The northern region of Australia is characterised by highly variable and summer-dominant rainfall. Wheat is planted in Autumn on stored soil moisture and relies on within season rain to avoid post-anthesis stress effects. In this region, wheat yield and grain quality are adversely affected by limited water in most years. We have recently embarked on an integrated field-to-gene-to-field program aimed at understanding the adaptation of wheat to water limited conditions in this northern environment. There are five components to our program. Firstly, the program is assessing germplasm for its performance under water limited conditions in northern Australia, with a focus on CIMMYT germplasm; a large variation in yield under severe water limitation has been observed. Secondly, we are investigating the physiological basis of germplasm that performs well. We are investigating the role of both previously identified water-use traits, such as transpiration efficiency (TE), and novel traits in our environment. Thirdly, we are investigating the role of management of germplasm in improving wheat yields in water-limited conditions. Fourthly, we are identifying molecular markers associated with adaptive traits that can be used for marker-assisted breeding. And finally, we are using genomic approaches to investigate the genes and regulatory sequences that underlie traits of relevance. We have identified both general drought responsive genes and regulatory sequences as well as genes and regulatory sequences for specific traits, such as TE.

P 8.31 - Genetic analysis of drought tolerance in tropical maize. I. QTL by environment interactions for flowering traits and grain yield.

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To dissect the genetic basis of drought tolerance in tropical maize, with a special emphasis on genotype by environment interaction (GxE), a recombinant inbred line (RIL) population was evaluated in eleven field experiments conducted in Mexico and Zimbabwe. Results related to yield components, flowering traits and plant height are discussed here. The combined analysis for male flowering (MFLW) across all stress environments identified an impressive set of 15 QTLs, 10 of them presenting a significant QEI, which underlines the impact of the environment on maize plant development and precocity. Despite the observed significant negative correlation between anthesis-silking interval (ASI) and grain yield (GY), no co-localization of QTLs was observed for these two traits based on the combined analysis. The bins 1.06, 4.06 and 10.06, however, were involved in the expression of ASI and GY in several individual stress experiments, accounting only for a small phenotypic effect. The bin 1.04 was of particular interest, since it comprised a major QTL for GY under well-watered conditions in Zimbabwe explaining 16% of the phenotypic variance. This QTL was also significant for plant height in all the experiments conducted in Mexico. QTLs for both GY and plant height have also been reported in the literature in this bin 1.04 (qgyld14, qplht18, MaizeGDB). Those results indicate the presence on bin 1.04 of a gene cluster controlling plant development under both stress and well-watered conditions.
P 8.32 - Genetic analysis of drought tolerance in tropical maize. II. Possible role of chlorophyll content and senescence in drought tolerance

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Relative chlorophyll content quantified in the ear leaf and the second leaf from the tassel as well as the whole plant senescence were measured twice during the flowering period on a RIL population segregating for drought tolerance in six field experiments conducted in Mexico. Four trials were performed under managed drought stress at flowering and two under well-watered conditions. Water-limited conditions induced a decrease in chlorophyll content in both target leaves - in the ear leaf to a bigger extent than in the young leaf - and senescence took place early on, compared to well water conditions, demonstrating some resources remobilisation under stress. The drought tolerant parent always had a higher relative leaf chlorophyll content and a lower senescence value compared to the drought susceptible parent, under both stress and well-watered conditions. Across stress experiments a relative reduction of chlorophyll content of 25 to 40% was observed. Higher chlorophyll content and delay in senescence can be considered as adaptive traits since both are negatively correlated with anthesis silking interval and "stay green" genotypes produced more grain. The leaf chlorophyll content under drought was mainly influenced by the three genetic regions located on the bins 2.04, 9.01 and 10.04, as revealed by the combined analysis across experiments. The QTLs in these regions explained up to 30% of the total phenotypic variance, although this value varied among experiments. The QTL on bin 10.04 showed little environmental interaction, since it was detected significantly for all the chlorophyll measurements as well as the whole plant senescence in three out of four drought stress experiments.

P 8.33 - Use of physiological as a molecular tools to breed drought resistant durum genotypes

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Earlier studies on durum adaptation in the Mediterranean dryland in our program indicated that physiological selection traits have the potential to improve genetic yield gains in durum wheat. This study will address some of the relation of the physiological traits with grain yield under dryland conditions. Examples of physiological traits, which could potentially be applied to improvement of cultivars in dry areas, are presented. The photosynthesis is the most important physiological process for improving plant productivity in general; and in the dry areas in particular. Mapping and QTL identification for photosynthesis parameters will be presented and discussed in relation with drought tolerance. Identification of genetic material that can carry on the photosynthetic activity under drought is of paramount importance for improving genetically yield productivity and stability in dry areas.
DNA markers of Brassica B genome may facilitate introgressing drought tolerance

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Relationship between Brassica species established by cytogenetic investigations has been represented as the triangle of U (1935). Three of the six Brassica species contain simple (diploid) genomes A, B and C; three other species are allotetraploids combining these genomes. Brassica species containing the genome B are well adapted to high temperature and lack of moisture (Kumar et al., 1984) and therefore can be utilized as the sources of drought tolerance in breeding. DNA markers of the B genome would considerably facilitate such breeding (Schelfout et al., 2004). Our study of dispersed repeat polymorphisms in six Brassica species produced several fragments specific of the genome B. The B genome-specific fragments from Brassica nigra (BB), B. juncea (AABB) and B. carinata (BBCC) were cloned and sequenced. The sequences from three species were 93-95% identical. Homology search in the public databases produced several non-annotated EST sequences from B. napus and B. oleracea; however, similar homologs from the B genome species have been found as yet. Currently we transform the cloned sequences into simple SCAR markers of the genome B.

Development of rice cultivars for rainfed lowland drought prone conditions in Thailand: integration of farmer participatory approach to the breeding program

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Major rice growing areas in Thailand are in rainfed lowland conditions in which grain yield is highly dependent on the amount and distribution of rainfall during the growing season, particularly in October and November, during the reproductive to grain-filling phases. Drought varies in timing and severities from place to place. Therefore selection of cultivars with specific adaptation to particular type of drought conditions is an objective of our breeding program. In year 2002, farmer participatory approach was introduced to our breeding program. Breeding materials including glutinous and non glutinous rice from the national breeding program were used. Ongoing project, breeding materials were evaluated in target areas covering range of rainfall patterns in upper part of North and Northeast Thailand. With collaboration between farmers and researchers, each year mother-baby trials were conducted at 17 villages in 15 provinces. When cultivars in each mother trial were in flowering period, farmers in the village were asked to gather at the trial. Farmers were asked to express their preference of cultivars by filling in ballots for voting. Following the voting, a focus group discussion was conducted to study farmers' perceptions in voting for their preferred cultivars. Occurrence of terminal drought, i.e. before flowering and continuing through maturity, affected performance of cultivars for grain yield. Cultivars with a good adaptation to drought conditions obtained high votes indicating preference of farmers. Under drought conditions, only early maturing cultivars performed yield well while later maturing ones showed a high percentage of sterility. Obviously, cultivars that farmers voted as their most preference cultivars had appropriate maturity matching hydrological conditions in the field. Farmer rating of preferred cultivars in baby trials using questionnaires and interviews showed that under a wide range of growing conditions and managements of farmers, some new cultivars introduced to farmers were superior cultivars to that being grown by farmers. Hence, a range of new cultivars was accepted.
P 8.36 - Drought resistance and microsatellites polymorphism in wild emmer wheat populations

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The joint effects of the domestication genetic-bottleneck and subsequent selection in man made agro-ecosystems have narrowed considerably the genetic variation in cultivated crop species as compared with their wild progenitors. Wild emmer wheat (Triticum turgidum ssp. dicoccoides (Körn.) Thell.), the tetraploid progenitor of cultivated wheat, thrives across wide ecogeographical range throughout the Fertile Crescent, and hence it offers a valuable source of allelic variation for various agronomically important traits, including drought resistance. Genetic diversity for drought resistance and microsatellite markers were examined in 110 accessions of wild emmer wheat consisting 25 populations originating from Israel and surrounding regions. Fifty six microsatellite markers (combining genomic SSRs and EST-SSRs), representing 14 chromosomes pairs of genome A and B, revealed wide genetic variation both between and more interestingly within populations. These findings correspond with our field experiments, showing wide genetic diversity for various drought related traits, under two irrigation regimes. Distribution of SSR alleles among populations was not random, revealing higher gene diversity values in populations originated from drought-prone environments. Associations between gene diversity and ecogeographical conditions of their collection-sites suggested that some microsatellites are not biologically neutral. Furthermore, the most outstanding drought-tolerance capacity was detected in populations from habitats affected by frequent events of extreme temperatures. Our results suggest that the high genetic variation found in the wild emmer wheat germplasm has the potential to improve drought resistance in cultivated wheat.

P 8.37 - DNA markers for drought tolerance in wheat

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Random Amplified Polymorphic DNA (RAPD) technique using Bulked Segregant Analysis was used to find DNA Markers linked to Drought Tolerance traits in wheat like Osmotic Adjustment, Leaf Water Potential, Relative Water Content etc. Segregating population from a cross of drought resistant and susceptible parents was used in the study. Five hundred primers were used to study the polymorphism between the bulks. DNA marker identified and its use in molecular breeding is discussed.
P 8.38 - Draught and salt-tolerant plants result from expression of H⁺ pyrophosphatase gene from Rhodospirillum rubrum

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Most of crop plants are extremely sensitive to water deprivation and high salinity that leads to significant decrease in yields under such conditions. One of the approaches to increasing salt tolerance of plants is based on the control of Na⁺ concentration, which can be achieved by increasing vacuolar solute accumulation. The sequestration of Na⁺ should increase the osmotic pressure of the plant and thereby reduce the toxic effects of this cation. In plants, the vacuolar H⁺-ATPase and the vacuolar H⁺-pyrophosphatase (H⁺-PPase) acidify the vacuolar lumen. Enhanced expression of any of these enzymes should increase the sequestration of Na⁺ ions in the vacuole by increasing the availability of protons to vacuolar Na⁺/H⁺ antiporter. We constructed transgenic Nicotiana tabacum plants overexpressing the gene encoding membrane H⁺ PPase from photosynthetic bacterium Rhodospirillum rubrum. We found that these transgenic plants are much more resistant to high concentrations of NaCl and to water deprivation than the wild-type plants. The transgenic plants accumulate more Na⁺ ions in their leaf tissue than the wild type. The increased salt and drought tolerance of transgenic plants may be explained by an enhanced uptake of cations into the vacuole that also lead to compensatory transport of anions to maintain electroneutrality. The resulted increased vacuolar solute content would confer greater water retention, allowing plants to survive under drought conditions.

P 8.39 - Developing drought tolerant finger millet (Eleusine coracana Gaertn) by expressing mannitol dehydrogenase (mtld)

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Being a C4 species finger millet is highly adapted to arid conditions, but early stages of its seedling emergence and its further development is hampered by drought. Therefore increasing its desiccation tolerance has relevance. Mannitol is an osmolyte and act as potential sink for reductant energy and also scavenges hydroxyl radical; hence minimizes oxidative stress. In this study we developed transgenic finger millet lines expressing bacterial mtld gene and tested their performance under various abiotic stresses. Initially, Agrobacterium mediated transformation protocols were developed using pCAMBIA 1301 construct, which has gus reporter gene. Forty-five-day-old callus obtained from portion of the seed was infected with Agrobacterium culture (OD 600 0.6) for five minutes, co-cultivated for two days and selected on medium containing hygromycin. The integration pattern revealed by southern analysis and GUS assay confirmed the stable transformation. This forms the basis for developing transgenic mtld lines. Adapting the standardized protocols mtld was successfully transformed into finger millet. Southern analysis of T0 and T1 plants revealed the stable genetic transformation. T0 transgenic plants performed better when they exposed to methyl viologen induced oxidative stress compared to that of wild type plants. Seedlings of T1 plants showed better growth under PEG, salinity and menadione (compared to that of wild type). Stable second-generation mtld transgenics are being examined for their performance under moisture stress. In conclusion, Elucine coracana can be genetically transformed by Agrobacterium tumefaciens and expression of mtld gene enhanced the tolerance to abiotic stress.
P 8.40 - Comparative genetic analysis of tomato plant efficiency for water consumption under control and saline conditions

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Exposure to drought or salt stress triggers many common reactions in plants. Both stresses lead to cellular dehydration and removal of water from the cytoplasm into the extracellular space. The objective of the present research is the comparative analysis of quantitative trait loci (QTL) involved in water consumption (C) and its efficiency in dry mass yield (EUA), under control and salinity (100 mM NaCl) conditions, using a population of 115 F6 lines derived from the interspecific hybrid L. esculentum var. cerasiforme x L. cheesmanii. This population had been genotyped at 117 marker loci (mostly microsatellites). Four QTLs have been detected for C and seven for EUA, none of which is coincident. More QTLs are detected under salinity (three for C and five for EUA) than under control conditions. This agrees with differences in sensu lato heritabilities between treatments for both traits (0.42 and 0.53 for C; 0.21 and 0.48 for EUA, respectively). Over- and under-dominant gene effects are detected in seven out of nine QTLs at codominant marker loci. Esculentum alleles or heterozygotes show the highest values of EUA at four genomic positions where fruit weight QTLs are also located. Thus, higher efficiency in water utilization in this population is genetically associated with larger fruits at these positions. None of the cheesmanii alleles increases EUA in comparison to esculentum alleles although the wild parental is able to yield fruits at higher salinity levels than the cultivated one. Another population of 142 F6 lines, derived from the same female parental and L. pimpinellifolium, was used to dissect these traits for comparative purposes. Four QTLs were detected for C and only one for EUA. The pimpinellifolium allele is associated with lower C means at three QTLs, and larger roots at one of them. A broad genetic variability among populations exists for C.

P 8.41 - Linking physiological and genetical genomic approaches to understand drought tolerance in a fast growing tree crop, Populus

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Populus is a genus of fast growing temperate trees that have potential for wood, fibre and biomass for energy production. In addition, Populus trichocarpa is the first tree for which the full sequence of DNA is known and for which other genetic and genomic resources are available including microarrays and populations for QTL detection. We have subjected a mapping population consisting of grandparents, F1 and 200 F2 individuals to a controlled drought treatment. In a second approach we have compared the performance of this population when subjected to drought at a largely wet site (UK) with a largely dry site (Italy). This has shown that the two grandparents of this cross have contrasting responses to drought. Visible symptoms developed in P. trichocarpa within hours of soil drying whilst P. deltoides appeared more resistant to drought, perhaps reflecting selection of these species from relatively wet and dry climates respectively. We have identified a large number of QTL for this and other responses to drought in the F2 progeny, including altered leaf expansion, cell size and cell production. These have been linked to the physical sequence and candidate genes identified to explain traits. In a complementary approach we have assessed contrasting transcriptomic responses using microarrays for both parent and ‘extreme’ F2 genotypes in both control and drought conditions. Our latest results will be presented.
P 8.42 - Effect of nutrient supply on plant growth and nitrate assimilation of soybean (Glycine max L.) under drought conditions

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The effects of phosphorus (P) and iron (Fe) nutrition on plant growth, nitrate content and nitrate reductase activity in roots and leaves of soybean (Glycine max L.) in relation to moisture regimes of soil were studied. The pot experiments with soil culture were performed in greenhouse conditions. Phosphorus treatments were applied at dose 200 mg kg⁻¹ soil (sufficient treatment) and without its application (insufficient). Iron foliage nutrition was administrated as Fe-EDTA (0.02%) five days before the start of the drought period. The water stress conditions were imposed for 14 days. The influence of nutrients on biomass production and activity of nitrate reductase was more pronounced in normal water conditions. The addition of P reduced drought inhibition of growth. Iron supply did not significantly change plant production. Water stress decreased the level of nitrate reductase activity more significantly than nutrient deficiency. Phosphorus nutrition has stimulated the nitrate transport from roots to shoots, shifting the main nitrate reduction. The level of nitrate content in roots was less affected by iron nutrition. The practical importance of these researches is that soybean production and nitrogen assimilation may be improved by phosphorus and iron supplies in normal moisture of soil as well as in the water stress conditions.

P 8.43 - A Gaspé Flint x B73 introgression library to identify QTLs for drought-related morpho-physiological traits in maize

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An introgression library (IL) is a collection of lines each carrying a molecular marker-defined chromosome segment introgressed into the genetic background of an elite line. ILs are an ideal tool for dissecting complex traits such as those (e.g. flowering time, root architecture, etc.) influencing the adaptive response to drought. The aim of this research is to produce a collection of maize IL lines with the genome of the early-flowering Gaspé Flint introgressed into the medium-late line B73. Among the IL lines collection in the B73 background, the Gaspé Flint genome will be fully represented, thus allowing us to dissect the genetic components controlling the large difference in flowering time and root architecture. The IL collection will also serve as a permanent source of nearly isogenic material for QTL analysis and cloning for many other morpho-physiological traits, such as plant height, number of nodes and tiller, leaf area, root architecture, yield components, etc. The IL collection has been produced by a marker-assisted backcross based on SSR markers. Currently, plants of the BC5 generation have been grown in winter nursery and selfed to identify the plants homozygote for the introgression. The average Gaspé Flint introgressed segment length is 20-30 cM, which requires the production of ca. 80 IL lines to cover the maize genome. A genetic map based on the first generation of marker-assisted backcross will be presented. Preliminary results have shown the effectiveness of the IL for mapping QTLs influencing flowering time and root architecture at the seedling stage.

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P8.44 - SNPs analysis in drought tolerance candidate genes in Aleppo pine

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Single nucleotide polymorphisms are emerging as an important tool for the assessment of genetic diversity and, if detected in candidate genes, may allow gathering information about adaptive variation. Aleppo pine (Pinus halepensis) is an outcrossing highly heterozygous species, with very large effective population sizes. In the present study we report on SNP discovery, level of nucleotide polymorphism, haplotype structure and linkage disequilibrium for nine candidate genes related to drought stress tolerance in natural populations of Aleppo pine. Six natural populations were sampled along a geographical and ecological gradient (Greece, Israel, Algeria, Morocco, Spain, Italy). The nine candidate genes were amplified in at least eight individuals per population and sequenced from both ends. Sequences were aligned, the single point mutations were identified, their frequencies estimated and the haplotypes were determined. The frequency of SNPs and nucleotide diversity are on average lower than that observed in other conifer species. Tests for genetic differentiation among populations revealed a significantly high Fst value for some candidate genes, much higher than those estimated in Aleppo pine for neutral markers (isozymes and chloroplast microsatellites). The extent of linkage disequilibrium within some candidate genes, estimated by R2, showed the tendency of a rapid decline within few hundreds of base pairs, as already observed in other conifer species, which are typically outcrosser (e.g., Picea abies). Possible implications of these results in conservation genetics and QTL mapping will be discussed.

P 8.45 - Identification of transgressive variation associated with QTLs for drought resistance in interspecific (O. sativa x O. glaberrima) progeny

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Oryza glaberrima species is composed of three genetic groups corresponding to ecological adaptations to deep water (floating), lowland and upland. Deep water was the primary ecology of adaptation/domestication of the species. Interestingly, 10% of floating ecotypes were found to be drought tolerant under controlled severe drought screening both at vegetative and reproductive stages of growth, suggesting the potential for high genetic variation for the species within that group. This finding suggests that crosses between these ecotypes of O. glaberrima and drought tolerant O. sativa accessions are likely to generate transgressive segregants containing new combinations of genes for resistance to stresses such as drought. Transgressive variation is commonly observed in interspecific progeny and this offers the possibility of identifying superior offspring from crosses between two parents where neither represents the phenotypic extreme of interest. This has immediate implications for QTL mapping for drought resistance in rice. Interspecific hybridization between O. sativa x O. glaberrima has proven to be an efficient way to generate superior rice cultivars adapted to the difficult rice growing environments of Africa. To date, there has been little genetic analysis to determine which portions of these two genomes are complementary and which combinations of genes and quantitative trait loci (QTL) provide optimum performance in stress-prone environments. The power of QTL analysis is that it offers the ability to identify and ultimately clone genes underlying QTLs that are responsible for superior performance in the offspring of a bi-parental cross. QTLs associated with positive, transgressive variation are of particular interest. O. glaberrima accessions (CG 14, among others) identified as drought tolerant in replicated trials at WARDA (WARDA 1999) have been used in crosses with O. sativa cvs. Moroberekan and WAB56-104, drought-tolerant tropical japonica varieties cultivated in Africa. Interspecific backcross populations are being developed for QTL mapping. Our objective is to generate interspecific segregants with enhanced drought tolerance for African farmers and to map QTLs associated with a variety of drought-related characters. Such information would provide an invaluable guide for future breeding efforts.
P 8.46 - Better performance of transgenic tobacco plants over-expressing stress inducible P5CS gene under drought and salt stress

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A large number of plant species accumulate proline in response to drought and salt stress, suggesting a key role of this amino acid in plant stress adaptation. We compared the proline levels in transgenic tobacco (Nicotiana tabacum L.) plants over-expressing the Vigna aconitifolia P5CS driven separately by a constitutive CaMV 35S promoter and an ABA inducible promoter (4X-ABRE-35S). Under both water and salt stress, the plants expressing P5CS gene driven by stress inducible promoter accumulated nearly three to four-fold more proline than untransformed plants, but were on par with the constitutively expressing P5CS transgenic plants. Further, ABA treatment resulted in the highest induction of P5CS activity with a six to seven-fold increase in proline levels in ABRE-P5CS transgenics, where as the 35S-P5CS plants accumulated only four to five-fold more proline compared to the untreated plants. More interestingly, we found that stress inducible expression of P5CS transgene resulted in higher biomass production than compared to that of constitutive expression under stress. This study clearly indicates the significance of stress inducible promoter over constitutively active promoters in plant genetic engineering under stress, since constitutive over-expression of the transgene may compete for energy and building blocks for the synthesis of macromolecules, which are also required for plant growth under normal conditions.

P 8.47 - Identification of trait and molecular marker associated with components of drought resistance in rice (Oryza sativa L.)

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Improvement of grain yield in rice under low moisture stress is difficult using conventional plant breeding methods, and alternative strategies are needed. Some studies have demonstrated an influence of the root system on grain yield. However, to date, only simple correlation studies have been employed to assess the association between root morphological characters and yield components. In this study, canonical correlation analysis has been used in order to better understand the relationship between and among root morphological characters and yield components, under non-stress and stress conditions in rainfed lowland rice. STMs primer pairs that were earlier found to be polymorphic between the IR64 and Azucena were selected and used to screen the mapping population developed by a cross P124 x IR64. Genotyping of selected individual plants and co-segregation analysis of these data along with phenotypic measurements was lead to identify a total of four QTLs for root length under stress and non-stress conditions.
Diversity in *Hedysarum* species: potential use to improve grasslands in Tunisian semi-arid areas

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In Tunisia, local genetic resources have been currently damaged by severe genetic erosion due to over-grazing and reduction of range land. Thus, pastoral areas are currently relegated to the dry lands which are dominated by an irregular rainfall. Among crops that are reliable to promote pastoral zones,*Hedysarum* genus (*Fabaceae*) is an important genetic resource contributing to pastoral production particularly in semi-arid and arid areas. Hence, elaboration of a strategy aiming at the genetic diversity's evaluation and the preservation of this important germplasm is imperative. Our investigations have been developed to obtain a deeper insight in this phytogenetic resource by the use of molecular techniques, such as restriction fragment length polymorphism (rDNA-RFLP), inter-simple sequence repeats (ISSR) and amplified fragment length polymorphism (AFLP). On the whole, molecular markers showed high degree of polymorphisms six *Hedysarum* species in Tunisia, these concerns either intra- or inter-specific level. These markers allowed us information about the phylogenetic relationships and contribute to fingerprint the local *Hedysarum* accessions. In addition, considerable variability has been detected in the case of populations that are characterized by a maximum phenotypic diversity (opposite geotropisme). Amplified fragment length polymorphic (AFLP) has been proposed as a valuable tool for finding molecular markers linked to QTL controlling architectural trait. Hence, we may assume that some of the revealed molecular markers are strongly correlated with important agronomic traits and implicate in forage and seed productions would be suitable to improve selective program.

Results of a survey on marker-assisted selection for drought tolerance

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Marker-assisted selection (MAS) has become increasingly popular as a means to generate congenic strains (e.g. NILs, ILs, etc.) and to improve crops' performance. The dissection of quantitative traits into their single components, the so-called QTLs, provides a direct access to genetic diversity for physiological processes that regulate the adaptive response to drought. However, despite the large number of QTLs described to influence yield in drought-stressed crops, the overall impact of MAS on the release of drought-resilient cultivars has so far been marginal. The present survey assessed to what extent MAS has been and is being exploited by public and private research groups in order to improve drought tolerance. In total, 26 replies were received from the 46 groups that were contacted. The responses evidenced that MAS is prevalently used to facilitate backcrossing procedures in order to create isogenic materials at target regions rather than for the direct improvement of existing materials. The following reasons were indicated (in decreasing importance) as the main limitations to a more widespread use of MAS for the release of cultivars with an improved drought tolerance: lack of resources, complexity of drought-related traits, genotype x environment interaction, lack of major QTLs, excessive number of QTLs, germplasm evaluation, lack of robustness of QTL effects, lack of user-friendly markers and linkage drag. Most repliers (70%) felt confident that MAS will eventually contribute to improve drought tolerance, while the remaining 30% remain uncertain. The present survey indicated the willingness of the repliers to continue utilizing MAS in future activities.
P 8.50 - Identification of marker loci responding to selection for grain yield under reproductive-stage drought stress in seven rice crosses

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In an experiment involving seven upland/lowland rice crosses, shifts in SSR marker allele frequencies resulting from selection for yield under reproductive-stage upland drought stress during the dry seasons of 2003 and 2004 were monitored. From 200 to over 400 random F2-derived lines were initially screened for yield in 2003 under both severe upland stress and lowland non-stress conditions. Allele frequencies of SSR markers in upper tails selected in the control and stress environments were compared; alleles whose frequency differed in the stress- and non-stress-selected tails were assumed to be linked to QTL associated with differential stress response. In each cross, a few marker loci exhibited significant stress-related frequency shifts, but these loci did not consistently occur in the same region in different crosses. The crosses Apo/IR64 and Vandana/IR64 were subjected to a second round of divergent selection during the dry season of 2004. In Vandana/IR64, in which genotyping is underway, seven loci responded markedly to selection under severe stress in 2004. The largest shift was observed at RM510 on chromosome 6. Here, the frequency of the Vandana (upland) allele in the upland-selected fraction was 0.62, compared to 0.30 in the lowland-selected fraction. The initial frequency of the Vandana allele was 0.38 in both environments. Allele frequencies at marker loci in this region also responded to selection in two other populations (Apo/IR64, Bala/IR64). Overall, these results are consistent with a hypothesis that only a few of the genes affecting upland drought tolerance have large, additive effects, and that favorable alleles for such genes are dispersed in the rice germplasm.

P 8.51 - Genetic variation for maize seedling root growth under water-deficit stress

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Genotypes often differ in their responses to environmental change, resulting in a change in their relative rank when grown in different environments. We have investigated the magnitude of G x E interaction for a critical trait in the plant response to water-deficit stress, namely the maintenance of root growth, using a locally adapted population of inbred lines. Employing a hydroponic system to characterize primary root growth rates of seedlings under several water-deficit stress treatments, we found that the rank of genotype growth rates changes across conditions and that genotypes vary most for recovery from water-deficit stress rather than during water-deficit stress. A genomic survey of 122 loci within the lines identified two loci on the top of chromosome 10 that strongly correlate with growth rate during stress recovery. We are initiating global gene expression profiling experiments and introgression of the top of ch10 into a uniform genetic background to characterize the genes and loci that may explain the observed G x E interaction.
P 8.52 - QTLs for drought avoidance and tolerance identified in a set of random introgression lines of rice

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A large set of 254 introgression lines in an elite indica genetic background were evaluated for grain yield and related traits under the irrigated (control) and drought (stress) conditions in two consecutive years for genetic dissection of adaptive strategies of rice to water stress. A total of thirty-six QTLs affecting heading date (HD), plant height (PH), grain yield (GY) and yield components were identified and most QTLs showed pronounced differential expression either qualitatively or quantitatively in response to drought. These QTLs could be grouped into three major types based on their behaviors under control and stress conditions. The first type of DT QTLs was associated with trait stability and the Teging ( indica) alleles at all QTLs increased trait stability (reduced trait difference). The second type of QTLs comprised those that behaved consistently under stress and non-stress conditions. The third type included QTLs behaving very differently across the stress conditions and thus expectedly contributing to trait instability and drought susceptibility. The observation that the Lemont ( japonica) alleles at all HD QTLs except QHd5 resulted in early heading under stress appeared to be responsible for the putative adaptation of Lemont to drought by escaping, whereas the Teging ( indica) alleles at most PH/ GY QTLs were consistently associated with increased yield potential and trait stability, suggesting the two adaptive strategies in the parental lines are under possible negative regulation of two largely non-overlapping genetic systems.
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