

Summaries Abdelly/Öztürk/Ashraf/Grignon: Biosaline Agriculture and High Salinity Tolerance

Section I: Physiology and biochemistry

Summary

Hans-Werner Koyro, Nicole Geißler, Sayed Hussin and Bernhard Huchzermeyer
Survival at extreme locations: Life strategies of halophytes – the long way from system ecology, whole plant physiology, cell biochemistry and molecular aspects back to sustainable utilisation at field sites

High concentrations of sodium are toxic to most plant species. Drought and soil salinity are the major abiotic stresses in plant productivity worldwide. Many glycophytic crop species are negatively affected. Physiological and biochemical research – with an accelerating emphasis on molecular biological studies – has shown that salt tolerance in halophytes depends on a range of adaptations. The multifactorial response embraces many aspects such as gas exchange, water relations (osmotic adaptation), selective transport and uptake of ions, ion compartmentalization (homeostasis), osmolyte production, enzyme activities, ion excretion and genetic control. The ability of plant cells to maintain low cytosolic sodium concentrations is an essential process for the ability of plants to grow in salty habitats and depends on several plant-specific interactions. Unfortunately, there are few investigations that combine studies of growth with the individual partially intracellular plant characteristics. Such joint investigations are the basis for the discovery of traits that present the ability to produce cash crops in saline environments. One possible solution could be rapid advances in the genetic transfer of halophyte salt tolerance traits to crop plants. Another is the breeding of cash crop halophytes.

Keywords: water crisis, halophytes, salt resistance, sustainable use, breeding, cash crop halophytes

Summary

Mohammed Ashraf, K. Nawaz, Habib-u-Rehman Athar and S.H. Raza
Growth enhancement in two potential cereal crops, maize and wheat, by exogenous application of glycinebetaine

Ameliorative effect of exogenously applied glycinebetaine (GB) on growth, photosynthetic and antioxidant capacities of two potential cereals wheat (cv. S-24) and maize (cv. Golden) grown under salt stress was assessed in two different independent experiments. Plants of maize were grown at 0 or 10 dS/m NaCl, while those of wheat were subjected to 2.17 or 14.67 dS/m NaCl salinity. Different levels of GB, i.e., 0 (unsprayed), 50 and 100 mM (in 0.10% Tween-20 solution) were applied as a foliar spray to both wheat and maize plants at the vegetative growth stage. Salt stress reduced the growth and yield of both maize and wheat plants. However, salt-induced reduction in growth and yield of both maize and wheat was ameliorated by exogenous application of GB, but this enhancement effect was more in wheat than that in maize. Furthermore, this GB-induced growth and yield enhancement was positively associated with increased endogenous GB, photosynthetic capacity, and superoxide dismutase (SOD) activity. Although exogenous application of GB improved photosynthetic capacity of both maize and wheat by increasing stomatal conductance, and thus favoring higher CO₂ fixation rate, this effect seemed to be partial in maize. In addition, the GB-induced reduction in transpiration rate in wheat compared with that in maize was found to be an additional factor that might have contributed to a better growth and yield of wheat under salt stress. The activity of only SOD was enhanced by GB application in both maize and

wheat under saline conditions. Thus, it is likely that both applied GB and intrinsic SOD scavenged reactive oxygen species in these potential cereals under saline conditions. In view of all these findings, it can be concluded that the adverse effects of salt stress on cereals such as maize and wheat can be alleviated by the exogenous application of GB, which in turn enhances photosynthetic capacity and modulates activities of antioxidant enzymes. Furthermore, effectiveness of GB application on regulation of photosynthetic and antioxidant capacities was found to be species specific.

Keywords: growth, yield, salt tolerance, photosynthesis, antioxidant capacity, stomatal conductance

Summary

Rosa M. Pérez-Clemente, Almudena Montoliu, Patricia López, María F. López-Climent, Vicent Arbona and Aurelio Gómez-Cadenas

***In vitro* tissue culture approaches for the study of salt stress in citrus**

On the Mediterranean coast of Spain, where most of the citrus are cultivated, water restrictions together with water overexploitation lead to the increase of salt concentrations in the irrigation water. Therefore, a significant number of citrus trees grow under salt-stress conditions. In this work, an *in vitro* experimental system has been developed to study the toxic effect of NaCl on citrus rootstocks, avoiding the ion filter that represents the root system. For this, internodal stem segments of Carrizo citrange, Cleopatra mandarine and Swingle Citrumelo CPB4475 were disinfected and the explants cultivated in an enriched MS medium. Once the newly emerged shoots reached 1.5 cm, they were transferred to control MB medium or to a medium containing MB salts plus 60 mM NaCl. Using this experimental system, the percentage of plants affected by high salinity was very similar among the three genotypes studied, despite their different tolerance under field conditions, indicating that on eliminating the root system, most of the citrus genotypes will have the same behavior under salt stress. Overall, this *in vitro* culture system is a good tool to study biochemical processes involved in the response of citrus to salt stress.

Summary

Annalisa Incerti, Riccardo Izzo, Adalgisa Belligno and Flavia Navari-Izzo

Sea water effects on antioxidant production in berries of three cultivars of tomato (*Lycopersicon esculentum* Mill.)

Tomato is moderately tolerant to salt. However, under stress conditions, antioxidative defence mechanisms in tomato are activated. The effects of diluted sea water on the antioxidant capacity, namely ascorbate, tocopherols and cellular redox status, have been evaluated in three tomato cultivars. Two salad tomato cultivars, Jama and Gimar and a cherry tomato cv. Naomi were used. Our results indicate that the three cultivars had different salt tolerance. Naomi showed the best adaptive response due to its increased antioxidant pool after salinisation.

Summary

Silvia Donnini, Graziano Zocchi, Antonella Castagna, Chedley Abdelly and Annamaria Ranieri

Identification of morphological, biochemical and physiological parameters useful to characterize nutritional stress status in Arboreous species differently tolerant to chlorosis

Lime-induced chlorosis is one of the major abiotic stresses affecting fruit tree crops in the Mediterranean area. However, fruit tree species have been the object of only few studies and the results obtained are insufficient to supply parameters for breeding. Here we report the results of a study carried out to identify morphological and biochemical modifications induced by low iron availability and a high level of bicarbonate in the medium in pear (cv Conference; tolerant genotype) and quince rootstocks (MA and BA29; susceptible genotypes) cultured by *in vitro* and hydroponic culture. Morphological parameters of *in vitro* plantlets were differently influenced by the two stress conditions depending on plant genotype and parameter analyzed, and suggested that the pear cv carried out an adaptive strategy to warrant sufficient iron supply, whereas the two quince rootstocks failed to adapt to conditions typical of calcareous soil. The strong and generalized reduction in chlorophyll and carotenoid content observed only in quince plantlets suggests a down-regulation of the whole chloroplast machinery in iron-deficient quince. Measurement of Fe(III)-chelate reductase activity (FCR) of rooted cuttings from *in vitro* culture grown in hydroponic solution suggests the probable involvement of enhanced FCR activity in the major tolerance of cv Conference to iron chlorosis. Cv Conference was also less sensitive to bicarbonate supply than quince rootstocks in terms of reduction of leaf pigment content and activation of the photoprotective xanthophyll cycle. In conclusion, this study shows that the mechanisms of differential Fe efficiency are associated to differences in leaf pigment content and photoprotective process and that *in vitro* culture could be a valid technique to test rootstock susceptibility to iron chlorosis.

Keywords: bicarbonate, carotenoids, chlorophyll, *Cydonia oblonga* Mill., Fe(III)-chelate reductase activity, iron deficiency, *in vitro* culture, lime-induced chlorosis, morphological parameters, pear, *Pyrus communis* L., quince, xanthophylls cycle

Summary

Riccardo Izzo, Annalisa Incerti and Claudio Bertolla

Sea water irrigation: effects on growth and nutrient uptake of sunflower plants

The aim of the present research was the evaluation of the effects of irrigation with diluted sea water on main morphological characteristics of sunflower plants (cv. Katharina, Piacenza ecotype). Plants, irrigated with fresh water or with 20% or 30% sea water during the whole biological cycle, were harvested at four growth stages. At each stage, the main growth parameters were measured and the principal nutrients were quantified. In particular Cl⁻ and Na⁺ increased significantly, especially in the plants irrigated with 30% sea water. Both sea water concentrations reduced N content but did not affect P content. K⁺ and Ca²⁺ decreased during the growth.

Summary

Karim Ben Hamed, Dorsaf Messedi, Annamaria Ranieri and Chedly Abdelly

Diversity in the response of two potential halophytes (*Batis maritima* and *Crithmum maritimum*) to salt stress

In this study, we compared the response to NaCl of *Batis maritima* and *Crithmum maritimum*, two potential halophytes with a different range of salinity tolerance. At high NaCl concentrations (800 mM for *B. maritima* and 300 mM for *C. maritimum*), the growth of both plants was significantly reduced. A split root experiment aimed at determining whether high NaCl conditions limit growth of plants through toxic effects of excessive salt accumulation in shoots or through impairment of some essential nutrient acquisition. The split root experiment was performed with three treatments. In the first treatment (B/S), half of the roots were immersed in a basal medium (B) and the other half in the same medium supplemented with NaCl (S). In the two other treatments, the two halves

of the root system were immersed either in salt-free medium (B/B) or in the basal medium containing salt (S/S). Under split-root conditions, *B. maritima* and *C. maritimum* accumulated Na in their shoots, and displayed improved growth as compared to control plants. In *C. maritimum*, the B/S treatment partially restored K provision to the shoots but not that of Ca suggesting that the inhibition of K⁺ uptake by salt could only limit its growth under high salinity. In *B. maritima* (B/S plants), the concentration of K⁺ and Ca²⁺ were diluted by growth. The inhibition of K⁺ and Ca²⁺ uptake by salt did not seem to limit growth of *B. maritima* growth under high salinity. The growth of *B. maritima* and *C. maritimum* could be also limited by the restriction imposed by NaCl on N uptake.

Keywords: *Batis maritima*, calcium, *Crithmum maritimum*, growth, halophytes, potassium, sodium, split root system

Summary

Virginia M. Luna, Analía S. Llanes, Laura R. Sosa, Mariana A. Reginato and Herminda E. Reinoso

Differential effects of sodium salts on the germination of a native halophytic species from South America: *Prosopis strombulifera* (Lam.) Benth.

Prosopis strombulifera is a halophytic shrub frequently found in the salinized areas of central Argentina. Interactions between temperature, ionic and osmotic components of salinity, and seed germination in this species are discussed in this chapter. Besides the osmotic effect, specific ion effects of salts play an important role in seed germination causing toxicity to the embryo. In saline soils where *P. strombulifera* is frequent, NaCl and Na₂SO₄ proportions are similar. Germination experiments with both salts, their iso-osmotic anionic and cationic mixtures and polyethylene glycol (PEG) were performed at 30°C and 35°C; the germination percentages registered with PEG were lower than those obtained with iso-osmotic Na-based monosaline solutions at osmotic potential (Ψ_o) of -1.2 MPa and lower, but greater than those in the salt mixtures, indicating that seeds were mainly affected by an osmotic effect rather than by ionic toxicity at 35°C. The salt mixture accentuated ion toxicity showing that germination is inhibited by a combination of osmotic and ionic effects, the latter having greater influence at very high salt concentrations. The excess of Cl⁻ or SO₄²⁻ anions in both cationic mixtures produced equal magnitude of toxicity on the seeds. Although a deleterious effect of potassium was also observed, the anionic effects were evidently much more marked. From Ψ_o of -1.2 MPa and lower, germination inhibition increased when salt concentration increased as the ionic effects were additive to osmotic effects. The germination percentages obtained with monosaline solutions at 35°C were superior to those obtained at 30°C, indicating that temperature played an important role in the germination response of this species by diminishing the osmotic effect of salt only in the case of monosaline solutions; however, the toxic effect of ions was accentuated when they were combined. Nevertheless, a partial reversion of sulfate toxicity was observed when seeds were placed in anionic salt mixtures at 30°C, demonstrating the differential effects of temperature on the osmotic and ionic components of salinity.

Summary

Haythem Mhadhbi and Mohamed Elarbi Aouani

Growth and nitrogen-fixing performances of *Medicago truncatula*-*Sinorhizobium meliloti* symbioses under salt (NaCl) stress: Micro- and macro-symbiont contribution into symbiosis tolerance

The effect of salt (NaCl) stress on plant growth and nitrogen-fixing apparatus was studied for symbiotic associations established between three *Medicago truncatula* lines inoculated and two *Sinorhizobium meliloti* strains. Salinity modulated all parameters analyzed as indices of growth performance, nitrogen-fixing capacity (acetylene-reduction assay) and nodule antioxidant system. Under stressful conditions, symbioses showed variability of response to salt application. Contrasting symbiotic associations were identified for nodulation, nitrogen-fixing capacity and salt tolerance. The total variance of analyzed performance indices under stressful conditions depended essentially on plant genotype factor. In nodules, the NaCl application had a decreasing effect on the rates of protein content and some antioxidant enzymes mainly catalase. Other enzymes such as guaiacol peroxidase increased in stressed nodules.

Summary

Hela Mahmoudi, Houneida Attia, Imen Tarchoun, Zeineb Ouerghi and Mokhtar Lachaâl
Physiological responses of two *Arabidopsis thaliana* isolates, N1438 and Col, to different salts

Growth inhibition by salt stress in glycophytes like *Arabidopsis thaliana* is associated with a significant accumulation of Na^+ and Cl^- in rosette leaves and to a reduction of their supply of essential nutrients such as potassium and calcium. In the present work, we attempted to evaluate the contribution of each of these factors to changes in the physiological functions of the species. The experiments were carried out under greenhouse conditions. Three-week old plants of *A. thaliana* from *Col* and *N1438* isolates were cultivated for 17 days in a basal medium supplemented with either 12.5 mM Na_2SO_4 , 12.5 mM K_2SO_4 , 25 mM NaCl, or 25 mM KCl. A salt-free medium was used as control. On harvesting, plants were cut into rosette leaves, bolts, and roots, and their fresh and dry weights, water contents, and major nutrient contents were determined. In *Col*, growth was decreased more by K^+ salts (KCl and K_2SO_4) than by Na^+ salts (NaCl and Na_2SO_4), and more by K_2SO_4 than by KCl, whereas in *N1438*, no difference was observed between the different salt treatments. Sodium was primarily accumulated in shoots, where it was probably compartmentalized into vacuoles, since it seemed to participate in osmotic adjustment. The growth sensitivity of *Col* to K^+ salt treatments was associated with excessive accumulation of K^+ in plant tissues. In conclusion, the variability of salt responses in *A. thaliana* was more dependent on cations (Na^+ or K^+) than on their associate anions (Cl^- or SO_4^{2-}).

Keywords: *Arabidopsis thaliana*, growth, nutrient acquisition, NaCl, KCl, Na_2SO_4 , K_2SO_4

Summary

Hela Ben Ahmed, Dorra Ben Ammar and Ezzeddine Zid
Physiology of salt tolerance in *Atriplex halimus* L.

Atriplex halimus is a common shrub in Tunisia, which represents a palatable food for sheep and camels. Furthermore, its halophytic behavior makes it a model for the study of mechanisms of salt tolerance in plants. We present here results obtained on *Atriplex halimus* var. *halimus*. In this species, the germination of seeds is very sensitive to salinity, since low concentrations of sodium chloride (50 mM) in the medium delayed the germination and reduced the capacity of the seedlings to emerge. Germination was completely inhibited, but reversibly, by NaCl concentrations up to 200 mM. Nevertheless, after the development of the radicle and the emergence of the cotyledons, which occurred 5 days after the imbibition of the seeds, the seedlings were able to tolerate this high concentration of NaCl and their growth was stimulated by salt. Also, 1-month-old plantlets, grown in a hydroponic medium, showed an optimal growth on 50–200 mM NaCl, and tolerated NaCl concentrations up to 300 mM. Our results indicate that, in *Atriplex halimus*, salt tolerance is

acquired at an early vegetative stage of the plant development, and is related to: (i) the absorption and transport to shoots of high quantities of Na^+ and Cl^- and their use in the osmotic adjustment, (ii) the efficiency of the vacuolar compartmentation of these ions, which prevents the ionic damage of the cytoplasm, and (iii) the aptitude of whole plant to ensure a sufficient supply of K^+ , by maintaining a high selectivity for this essential nutriment, in spite of large amount of Na^+ in the medium.

Keywords: *Atriplex halimus*, germination, growth, salt tolerance

Summary

Salma Daoud, Chérif Harrouni, Bernard Huchzermeyer and Hans-Werner Koyro

Comparison of salinity tolerance of two related subspecies of *Beta vulgaris*: The sea beet (*Beta vulgaris* ssp. *maritima*) and the sugar beet (*Beta vulgaris* ssp. *vulgaris*)

Sea beet (*Beta vulgaris* ssp. *maritima*), which has a real potential to become a cash crop halophyte in the Mediterranean region, and sugar beet (*Beta vulgaris* ssp. *vulgaris*), were studied with the aim of investigating the physiological mechanisms involved in these species to overcome high salinity. Four-week-old plants of the two species were grown for 7 weeks under greenhouse conditions in an automated culture system “quick check system” irrigated with tap water (control) and four seawater concentrations (25%; 50%; 75% and 100% seawater). The five treatments were fertilized with half Hoagland nutrient solution. Plants of the two species had 100% survival in all treatments with optimal growth in the low salinity treatment (25% seawater). Salinity tolerance of the two beets is related to their ability to accomplish osmotic adjustment by regulating their ion and water uptake from the culture medium. To avoid toxicity due to excess ion accumulation, the two species adjust their osmotic potential by accumulating large amounts of ions, especially Na and Cl, in shoot vacuoles and by the synthesis of compatible solutes in the cell cytoplasm. The reduction of stomatal conductance and transpiration participates in maintaining the level of leaf turgescence, and this may contribute to a long-term survival in saline environments. The high level of photosynthesis of the beets in high saline conditions shows that the reduction of growth in these conditions is not the consequence of photosynthesis reduction but of ion toxicity.

Keywords: *Beta vulgaris* ssp. *maritima*, *Beta vulgaris* ssp. *vulgaris*, sea water, quick check system, growth, osmotic regulation, ion composition, compatible solutes, transpiration, stomatal conductance, photosynthesis

Summary

Adalgisa Belligno, Marco Russo, Vito Sardo and Ju Ying Wu

Salinity influence on soil microbial population metabolism and enzymatic activities in lysimeter-grown *Olea europaea* and *Nicotiana glauca*

Since soil microorganisms are quite sensitive to changes in their habitat, their response in terms of selected metabolic and enzymatic activities was investigated as a possible indicator of the effects of saline irrigation in lysimeter-grown plants of *Olea europaea* and *Nicotiana glauca*. Water electrical conductivity ranged from 0.8 dS/m in the control to 8.9, 17.5, and 26.2 dS/m in treatments with 20%, 40% and 60% diluted seawater, respectively. While some results were non-significant, the following main conclusions could be drawn: Microbial biomass carbon, soluble soil carbon and respiration activity were not significantly correlated to salinity. In addition, the microbial biomass nitrogen was not correlated to salinity. Contrary to this, enzyme activities as shown by hydrolysis rate of fluorescein diacetate (FDA), acid and alkaline phosphatase, and β -glucosidase decreased

consistently with salinity without any significant difference between the two plant species. FDA gave the most sensitive and consistent response.

Section II: Ecology

Summary

Münir Öztürk, Aykut Güvensen, Serdal Sakçali and Güven Görk

Halophyte plant diversity from Irano-Turanian phytogeographical region of Turkey

Irano-Turanian phytogeographical region includes the central, east and southeast Anatolian geographical divisions of Turkey. The region is characterized by a continental type of climate with very cold winters and hot summers. Precipitation in the form of a heavy snowfall is seen usually in winter and rains are common in spring and autumn. However, the southeast experiences a steppe climate with very hot summers, severe aridity and evaporation. The area of saline and degraded soils in the region is increasing. The factors responsible for this are over-irrigation practices, and salt accumulation due to evaporation. In the region, 137 halophytic taxa belonging to 88 genera and 34 families are found. The genera *Salsola*, *Chenopodium*, *Limonium*, *Alhagi* and *Allium* include the highest number of taxa. Phytogeographically 80.29% of these taxa are Irano-Turanian and 13.14% are common. The number of endemic taxa is around 42. For a management of the saline-alkaline habitats sound information on plant diversity, vegetation cover, habitat types, and locations of species communities is needed, together with land cover maps, to follow the habitat deterioration and its causes. The present study will thus help in the determination of site quality.

Summary

M. Ajmal Khan and Raziuddin Ansari

Potential use of halophytes with emphasis on fodder production in coastal areas of Pakistan

Fresh water resources both for domestic and agricultural use are constantly depleting worldwide and crop yields suffer from a steady increase in soil salinity, especially in the arid and semi-arid areas. A burgeoning world population is a further threat to sustained food supply. Equally or even more affected in some cases, are other resources like fodder for animals and fuel wood for the rural poor. Efforts are hence needed to find an alternate source of water and utilization of saline lands for economic benefit. The varied climatic conditions of Pakistan offer opportunities for selecting suitable halophytes for specific purposes. Whereas halophytes may be used for a variety of purposes like food, fiber, fuel wood, medicines, source of chemicals, landscaping, ornamental, carbon sequestration, etc., one of the very important utilities lies in their use as fodder. An animal feeding trial showed that traditional green fodder (maize) and a halophytic grass (*Panicum*) were equally good for growth and development of 1-year-old cow calves. Meat from animals fed 100% *Panicum* was leaner and hence better for human consumption from health point of view.

Summary

M. Ajmal Khan, Farhat Agha and Bilquees Gul

Role of seed bank in the dynamics of desert communities

Sub-tropical deserts of Karachi, Pakistan are dominated by perennial shrubs and grasses, usually in a mono-specific stands. Seed bank dynamics of three stands about a kilometer away from the coast were selected and monitored for two years. These stands were dominated by *Atriplex stocksii*, *Cyperus arenarius* and *Cressa cretica*, respectively, with few individuals of other species in each

stand. Soil analysis of the *C. arenarius* community showed seeds of *A. stocksii* and *C. arenarius* were present throughout both of the seasons; however, only *A. stocksii* maintained a persistent seed bank that had some relationship with the aboveground vegetation. The *C. cretica* dominated community had a substantial presence of *C. arenarius* seed in the soil with some seeds of *C. cretica*, *Salsola imbricata* and *A. stocksii*. However, *C. cretica* maintained a small persistent seed bank showing a close relationship between seed bank and vegetation. *A. stocksii* maintained a large persistent seed bank during both seasons indicating a good seed bank-vegetation relationship.

Summary

Mohammad Kafi and Majid Jami-al-Ahmadi

Study of kochia (*Kochia Scoparia*) as a forage crop

The production of halophytes using saline waters and soils, and feeding livestock with them, is one of the most sustainable ways of conserving desert ecosystems and food production for people living in these areas. Therefore, to study the possibility of growing Kochia (*Kochia scoparia*) as a forage crop in desert environments with saline underground water, a research project was performed in Birjand, in the center of South Khorasan province, Iran. The rate and percentage of germination, radiation use efficiency (RUE), growth and ion accumulation in kochia were studied at three levels of saline irrigation water (1.5, 8.6 and 28.2 dS/m), three irrigation intervals and two plant densities (10 and 20 plants/m²). The results showed that salinity negatively influenced the majority of plant's morphological and physiological indices, yet the dry matter accumulation in the highest salinity level reached 60% of plants in lower saline levels, and even moderate salinity caused a small stimulus in plant growth and yield performance. However, mostly no difference was observed with the lowest salinity level. The radiation absorption of kochia rose as leaf area index (LAI) increased, and 95% of radiation was absorbed with an LAI equal to 4.5–5. In general, increase in salinity caused a delay in early season development, and accelerated plant maturity at late season. Kochia's adjustability for vegetative growth and forage yield show no response to plant density, but the seed yield increased on increasing the plant density. In conclusion, the Kochia's high production capacity, desirable digestibility and crude protein content in the presence of salinity and other desert stresses, such as high temperature and drought, make this plant suitable as a forage crop in harsh environmental conditions.

Keywords: radiation use efficiency, growth, yield, germination, salinity, temperature

Summary

Cristina M. Monteverdi, Marco Lauteri and Riccardo Valentini

Biodiversity of plant species and adaptation to drought and salt conditions. Selection of species for sustainable reforestation activity to combat desertification

Soil salinity is a threat for many agriculture and forest communities. Particularly ecosystems surrounding desert and coastal areas need to be preserved and restored for their intrinsic ecological value and vulnerability. Knowledge on physiology and ecology of plant tolerance, resistance and adaptation to salt exposure is fundamental to face land degradation and related desertification processes. Studies of physiological adaptive traits are important to select suitable species for a sustainable management of rural and forest environments. Salinity affects productivity of plant species. Moreover the capacity to tolerate salinity is widely variable at intra and inter-specific level. It is known that variations of photosynthetic performances and related parameters (e.g. leaf area) are mainly responsible of growth reduction under salt stress. Generally salinity limits CO₂ availability at the carboxylation sites. A reduced assimilation rate is often accompanied by a more than

proportional decrease in transpiration rate. Thus salt stress conditions usually determine an increase of instantaneous water-use efficiency (WUE). The investigation of salinity tolerance in natural environments is not easy because of climatic factors and field heterogeneity of salty soil. Moreover, because of the multiple and complex physiological responses to salinity, it is very important to find a suitable index to properly integrate the different physiological processes involved. Carbon isotope discrimination (Δ) in plant material has been demonstrated by several studies to be a promising approach that integrates physiological processes on different time-scales under both drought and salt conditions. Carbon isotope discrimination is directly related to the ratio of intercellular to atmospheric partial pressure of CO_2 (p_i/p_a) and negatively related with WUE. Moreover it is a relatively low-cost, easy and non-invasive technique to investigate ecophysiological traits of plant species in controlled and field conditions. A brief overview and perspectives in applying carbon isotope discrimination in ecophysiological studies, related to salinity and drought tolerance, are shown.

Summary

Hassan M. El-Shaer and Mohamed H. El-Morsy

Potentiality of salt marshes in mediterranean coastal zone of Egypt

The Northern Coastal region of Egypt extends around 1000 km long and 30 km inland. Its major characteristics as an arid Mediterranean climate are limited rainfall that varies between 80 and 250 mm/year where a relative insignificant rain-fed agriculture is practiced. Rangelands and livestock production are the main common natural elements in the region. Socio-economic characteristics are based on tribal systems of nomads and agro-pastoralists. The local economy depends on livestock sales and trade of agricultural products. Salt marshes plant species are dominant and grow naturally and intensively in the saline environments. Such plant species could have great potentialities for many human and animal usages. The production and nutritive values of these plants are affected by different human and environmental factors that cause severe deterioration. Many salt marsh plants communities are of great interest to grazers in the Mediterranean Coastal zones of Egypt because of their prolonged production period, as they constitute good grazing in the dry season in summer and autumn, particularly for sheep, goats, camels and wildlife. However, the real potentialities of such salt marsh plants have not been fully exploited and evaluated for different purposes. The aim of this study is to survey, briefly, the salt marshes species, its habitats, potentialities and the ecological factors affecting their distribution in different areas of the Mediterranean Coastal zones of Egypt.

Keywords: salt tolerance plants, halophytes, salt marshes, animal feed, nutritive value

Summary

Irina N. Safronova

Studies on the halophyte desert vegetation in the Northern Caspian Region (Caspian Lowland and Mangyshlak)

Halophyte vegetation is a characteristic feature of the temperate desert of Turan, in the Northern Caspian Region – the westernmost part of Turan. It includes the Caspian Lowland and the Mangyshlak. The Caspian Lowland belongs to the steppe and desert regions. The boundary between these Regions runs along the Kuma River on the south-west of the Caspian Lowland (45° N) and further – along the Kuma-Manych Depression and the eastern slope of the Ergeni Height (45° E), reaches 47° N and then turns to the north-east, crosses the Volga river at 48° N and runs to the east along this latitude. The Mangyshlak lies completely within the desert region. It is situated to the south of the Caspian Lowland at the eastern shore of the Caspian Sea between 45° and 42° N. Halophytes play a great role in desert vegetation of the

Northern Caspian Region. They form communities that are confined to salted soils and to salted variants of zonal soils. The halophytes comprise a significant number of species, including the families *Chenopodiaceae*, *Poaceae* and *Asteraceae*, together with *Tamaricaceae* and *Limoniaceae*. The most numerous is the group of dwarf semishrub halophytes. Some shrub species and two semishrubs are common. Some species of halophilous perennial grasses and one annual grass are characteristic of the desert vegetation. Many species of the annual saltworts also occur. The halophytes can be divided into three groups: (1) those restricted to the solonchak (salt marshes); (2) those restricted to solonetz and takyrs; and (3) those with their distribution connected with the salted variants of the zonal soil types. The latitudinal (zonal) and longitudinal (regional) regularities are revealed in distribution of halophytic desert vegetation. Halophyte communities in the desert zone are of a great importance as pastures. There are well adapted to environmental conditions and suitable for phytomelioration of pastures with low productivity.

Keywords: temperate desert, Caspian Lowland, Mangyshlak, halophytes, distribution, salted soils, solonets, solonchak, latitudinal and longitudinal regularities

Nariman Shamsutdinov and Zebri Shamsutdinov

Halophyte utilization for biodiversity and productivity of degraded pasture restoration in arid regions of Central Asia and Russia

Summary

Mokded Rabhi, Ons Talbi, Abdallah Atia, Chedly Abdely and Abderrazak Smaoui

Selection of a halophyte that could be used in the bioreclamation of salt-affected soils in arid and semi-arid regions

Vegetative bioremediation or bioreclamation of salt-affected soils is an economic solution mainly for developing countries since chemical additions are becoming increasingly expensive. However, to be efficient, this approach needs sufficient irrigation. In this investigation, we evaluated the ability of some halophytes to desalinize a saline soil under non-leaching conditions with the aim of selecting appropriate species that could be used for this purpose in arid and semi-arid regions where precipitation is too low to leach salts from the rhizosphere. Three perennial species were used in this experiment: *Arthrocnemum indicum* (Willd.) Moq., *Suaeda fruticosa* Forsk., and *Sesuvium portulacastrum* L. Seedlings were grown on a saline soil under greenhouse conditions and irrigated with tap water for 170 days. Irrigations were carried out with almost no leaching. Soil salinity was significantly reduced in halophyte-grown soil as compared to the control. Plants were able to decrease the soil electrical conductivity by absorbing soluble salts, mainly sodium ions. Among the three studied species, *Sesuvium portulacastrum* L. was the most productive and was able to accumulate in shoots nearly 30% of the sodium content of each pot over the 170 days. Thus, *Sesuvium portulacastrum* L. seems to be the most promising species for saline soil desalination in arid and semi-arid regions.

Keywords: *Arthrocnemum indicum* (Willd.) Moq., halophytes, non-leaching conditions, *Sesuvium portulacastrum* L., *Suaeda fruticosa* Forsk., vegetative bioreclamation

Summary

Kristina N. Toderich, Ismail Shoaib, Ekaterina A. Juylova¹, Abdullo A. Rabbimov, Batyr B. Bekchanov, Elena V. Shyuskaya, Lilya G. Gismatullina, Kozan Osamu and Toshpulat B. Radjabov
New approaches for biosaline agriculture development, management and conservation of sandy desert ecosystems

The major factors and current trends of soil salinization and rangelands degradation in the arid/semiarid zones of Aral Sea Basin were discussed. The bioremediation of abandoned saline lands using natural marginal resources could be considered as one of a number of strategies that can be employed to bring these lands back to their full production potential. Different ecological groups of halophytes were characterized according to taxonomy, mineral composition and salt tolerance. A positive relationship between mineral content of wild halophytes and biomass has been identified. Ion contents of evaluated wild native halophytes were relatively low and hence these species could be recognized as alternative forages, both in pure halophytic pastures and/or in mixture grass stands. Most of evaluated halophytes being late flowering and seed maturing species are recommended as a fattening feed during autumn and winter seasons, when there is a deficit of forages on the pasture lands. Introduction of strip cropping system represent an alternative for private farms in the livestock-based farming system, as well as a way to diversify feed resources under unfavorable environments. It also leads to the uniform distribution of good quality feed resources throughout the year and during difficult periods while preserving soils, water and phytogenetic resources. Another technique used in the salt-affected sandy desert environments is to plant shrubs as windbreaks to spare the land for other crops and help protect the soils from wind erosion and sand encroachment.

Summary

Aydar B. Nasrulin, Faruh Sh. Shaazizov and Helmut Lieth

Computer supported system for the risk assessment and action recommendation for the water objects in Uzbekistan based on the already developed databank

The water reservoirs in Uzbekistan were built about 50 years ago to manage agricultural irrigation for rice and cotton. Since the separation from Russia the country's needs for crops and water allocation are drastically changing. Due to world market conditions, the country now needs more food crops with less water requirement and the development of husbandry. The reservoir management had inflicted problems upon the Aral Sea with large impacts upon fisheries, natural forests and wildlife in the delta regions of the two rivers Amudarja and Syrdarja. For the future management of the large reservoirs upstream of both rivers new geographical information system-based decision support systems are under construction. This is needed to plan the water distribution for irrigation and urban usage as well as for risk assessments in case of catastrophic events and dam breaking. Here we present monitoring and modeling attempts for the management of all dam, reservoirs and pumping facilities in Uzbekistan.

Keywords: Uzbekistan, water reservoirs, dams, structural risks, hydrecological monitoring

Section III: Molecular biology

Summary

Isacco Beritognolo, Maurizio Sabatti, Mikael Brosché and Giuseppe Scarascia Mugnozza

Functional genomics to discover genes for salt tolerance in annual and perennial plants

With the progress in plant genomics, more and more information is being gained about genes that respond to different stresses. Microarray analyses of transcriptome regulation under salt stress have uncovered the complex gene networks involved in mechanisms of sensing, signaling, and short-term response. Most of this knowledge has been derived from shock-stress experiments conducted on one genotype under laboratory conditions, but the long-term acclimation to salt stress has been addressed by only few studies. The genes responsible for the variability of salt tolerance could be valuable resources in breeding programs but they are difficult to identify in typical microarray

experiments. The genes revealed by transcriptome analyses of salt-stressed plants are often common to other stresses and other species and do not explain the heritable variation. Comparative genomics is based on the comparison of genotypes differing in phenotypical behavior and is a promising approach to identify genes that control the heritable genetic variation of salt tolerance.

Summary

Arianna Latini, Maria Sperandei, Sandeep Sharma, Cristina Cantale, Massimo Iannetta, Marco Dettori, Karim Ammar and Patrizia Galeffi

Molecular analyses of a dehydration related gene from the *dreb* family in durum, wheat and triticale

Abiotic stresses are the primary cause of crop loss worldwide. They result in average yield losses of more than 50% in major crops. The negative effects of abiotic stresses are thought to be increasing due to global climate change and the resulting erratic weather patterns. Improving crops' ability to tolerate abiotic stresses through conventional breeding has been successful, especially in the case of wheat, as new cultivars better adapting to increasingly difficult growing conditions are being released regularly. However, as many stress-inducible genes have been identified, sequenced, characterized and insights into their functional roles in stress tolerance are being obtained, breeding programs have much to gain by exploring ways to target those stress-related genes that may be useful in their selection. If, or when, the relationship between different alleles or expression patterns of some stress-related genes is demonstrated, perfect markers for assisting breeder in selection for stress-tolerant lines can be readily obtained. Previously, we isolated and characterized the gene designated as *TdDRF1* encoding for a dehydration responsive factor in durum wheat. Results obtained using plant samples of different cultivars in time-course experiments conducted in the greenhouse suggested that the expression profile of *TdDRF1* upon water stress was genotype dependent. In the present paper we report results from field experiments carried at CIMMYT's experimental fields near Obregon in Mexico, in which quantitative RT-PCR was used to monitor the expression profile of the three transcripts produced by the *TdDRF1* gene under stressed (minimally irrigated) and non-stressed (fully irrigated) conditions. Tolerant and susceptible cultivars were analyzed and the results from these field experiments are compared with those from greenhouse testing.

Keywords: *Triticum durum*, triticale, real time PCR, water-stress, *DREB*-related gene, *TdDRF1*

Summary

Samia Daldoul, Michael U. Höfer, Claudia Linhard, Neila Jallouli, Ahmed Mliki, Götz M.Reustle and Abdelwahed Ghorbel

Expression analysis of salt stress responsive genes in grapevines

In Tunisia, highly tolerant autochthonous varieties represent a valuable resource for elucidating mechanisms of plant adaptation to salinity. Our aim is to determine which genes in these Tunisian grapevine varieties significantly contribute to the adaptation to increasing salinity. To characterize the complement of salt-responsive genes in Tunisian grapevines, we have constructed a subtractive cDNA library from leaves of *Vitis vinifera* var. *Razegui*, a highly salt-tolerant variety. The library was screened for differentially expressed cDNAs, and positive clones were verified. The expression pattern of selected candidate cDNAs was analyzed using a range of *Vitis vinifera* cultivars with different degrees of phenotypic salt-stress tolerance. Expression of these cDNAs was investigated in plants after 6 and 24 h of treatment with 100 mM NaCl in hydroponic culture, and compared to

plants grown under control conditions. Here, we describe the analysis of these transcripts and the putative correlation between phenotypic adaptation to salt stress and salt-induced gene expression.

Keywords: salt tolerance, gene expression, phenotypic variation

Summary

Mohsen Hanana, Olivier Cagnac, Toshio Yamaguchi, Saïd Hamdi, Abdelwahed Ghorbel and Eduardo Blumwald

Molecular biology and transport properties of grapevine Na^+/H^+ antiporter

Na^+/H^+ antiporters are involved in the transport of sodium and hydrogen ions across membranes and contribute in pH regulation of actively metabolizing cells. They play a primary role in homeostasis and are found in every biological kingdom, from bacteria to humans to higher plants. In plants, vacuolar Na^+/H^+ antiporters use the proton electrochemical gradient generated by the vacuolar H^+ -translocating enzymes, H^+ -ATPase, and H^+ -PP_iase to couple the downhill movement of H^+ with the uphill movement of Na^+ . Moreover, it has been shown that they compartmentalize Na^+ into the vacuoles for detoxification and improve consequently the salt tolerance in yeasts and plants. Recently, genes encoding these Na^+/H^+ antiporters have been identified and studied using a molecular genetic approach in the model systems *Arabidopsis* or *Saccharomyces cerevisiae*. We describe here the identification, cloning, molecular characterization and functional properties in yeast heterologous system of a vacuolar Na^+/H^+ antiporter from grapevine. To identify a Na^+/H^+ antiporter from grapevine we applied a candidate gene approach. A 1.83-kb genomic sequence adjacent to the *VvNHX1* gene was isolated using the thermal asymmetric interlaced-PCR. Histochemical localization of β -glucuronidase gene (GUS) activity was directed by *VvNHX1* promoter-GUS fusion in transgenic *Arabidopsis*. To determine the subcellular localization of the VvNHX1 protein by heterologous expression in yeast and transient expression in onion epidermal cells, chimera constructions were prepared using a modified green fluorescent protein mGFP6. An RT-PCR approach was used to examine the VvNHX1 mRNA levels in different organs and tissues of grapevine plants. To assess VvNHX1 transport properties, *VvNHX1* was expressed in the *nhx1* mutant TY001 (that lacks the endogenous Nhx1 Na^+/H^+ antiporter) and the rates of H^+ -coupled transport was measured by fluorescence quenching. Rates of cation-dependent proton movements in vacuoles isolated from yeast expressing *VvNHX1* were measured.

Keywords: antiporter, berry, grapevine, NHX, salinity, sodium, vacuole

Summary

Mohamed Ali Ghars, Elodie Parre, Anne-Sophie Leprince, Marianne Bordenave, Delphine Lefebvre-De Vos, Luc Richard, Chedly Abdelly and Arnould Savouré

Opposite lipid signalling pathways tightly control proline accumulation in *Arabidopsis thaliana* and *Thellungiella halophila*

Throughout evolution, plants have developed various strategies to tolerate water stress. Among them, the accumulation of proline has been reported in a wide range of species. The metabolic pathway of this compatible solute is relatively well characterized in *Arabidopsis thaliana*. However, the signaling cascades involved in its regulation remain largely unknown. *Thellungiella halophila*, which is a close relative of *Arabidopsis*, tolerates extreme salinity up to 500 mM NaCl. In this work, the involvement of lipid signaling pathways in the regulation of proline accumulation was investigated in these two species upon water stress. A pharmacological approach has been performed using specific inhibitors of key signaling elements. The effects of these inhibitors have

been investigated on proline accumulation. The present data show that phospholipases D (PLDs) are negative regulators of proline anabolism under normal conditions in *A. thaliana*. When such PLD-mediated regulation is abolished by 1-butanol, plants show a higher proline responsiveness to osmotic stress. In contrast to *Arabidopsis*, 1-butanol does not have any effect on proline accumulation in *T. halophila* under non-stress conditions. However, upon water constraints, 1-butanol reduces rather than increase proline accumulation. Our data suggest the involvement of a PLD-mediated signaling pathway in the tight regulation of proline metabolism that acts in a opposite way in *A. thaliana* and *T. halophila*. On the other hand, phospholipases C exert a positive control on proline accumulation in *A. thaliana* upon salt stress and a negative control in *T. halophila* upon water stress and non-stress conditions. In conclusion, we provide experimental evidence that positive and negative regulators are involved in the fine regulation of proline metabolism upon water stress. Our study has defined a critical role of lipid signaling pathways in proline accumulation in *A. thaliana* and in *T. halophila*. Thus, in *Arabidopsis*, our data indicate that PLC-based signaling is a committed step in proline biosynthesis upon salinity but not upon hyperosmotic stress.

Keywords : *Arabidopsis thaliana*, *Thellungiella halophila*, water stress, lipid signalling pathway, proline

Summary

Chamseddine Mediouni, Guy Houlné, Marie-Edith Chabouté, Mohamed Habib Ghorbel and Fatma Jemal

Cadmium and copper genotoxicity in plants

Heavy metal contamination in soils is easily transmitted to human through plants *via* the food chain. A major concern is to understand the plant response to heavy metal soil contamination to develop phytoremediation. Two plant models have been investigated in our study, the tomato, which is of agronomical importance, *Arabidopsis*, which is used as a model for molecular genetics. Heavy metal toxicity is described to induce oxidative stress linked to oxidation of proteins and membrane lipids but also to alterations of DNA damage response. We have investigated the metabolic response of cadmium and copper in parallel in both plant models and analyzed the transcriptional response of *Arabidopsis* RNR genes coding for isoforms of ribonucleotide reductase, an essential enzyme involved in DNA synthesis. Both Cd and Cu had a dose-dependent effect on plant growth. We also observed a rapid increase of catalase activity upon Cd or Cu treatments in tomato and *Arabidopsis*. At the transcriptional level, treatment with Cd resulted in a biphasic induction of two RNR genes in *Arabidopsis*; the first induction peak could be paralleled to the increase of the catalase activity.

Keywords: *Arabidopsis thaliana*, cadmium, catalase, copper, genotoxicity, *Lycopersicon esculentum*, thiobarbituric acid-reactive substances

Summary

Falleh Hanen, Riadh Ksouri, Wided Megdiche, Nejla Trabelsi, Mondher Boulaaba and Chedly Abdelly

Effect of salinity on growth, leaf-phenolic content and antioxidant scavenging activity in *Cynara cardunculus* L.

Cynara cardunculus L. (cardoon) is a medicinal plant widespread in arid and semi-arid regions where high salinity frequently occurs. Cardoon leaves are known for their high content of natural

bioactive molecules, notably polyphenols, that exhibit pharmacological activities such as antioxidant, antibacterial, and metal chelating activity. We studied the effect of different salt concentrations on plant growth, phenolic content and superoxide scavenging activity in locally grown *C. cardunculus* L. leaves (El Jem locality). No significant effect on leaf growth (leaf biomass, length and number) was found at moderate salinity (25–50 mM NaCl). However, these parameters were severely reduced (–30 to –90% as compared to the control) at 150 mM NaCl. Leaf phenolic content was significantly increased at 25–50 mM NaCl, and decreased at 150 mM NaCl. The superoxide anion scavenging capacity of leaf extracts was stimulated by salt treatment, with a maximum at the highest NaCl level. Our findings indicate that the two studied characteristics of *C. cardunculus* leaves (polyphenol content and O_2^- quenching capacity) were not modified in parallel with increasing salinity, and that only the polyphenol content was correlated with leaf growth.

Keywords: *Cynara cardunculus* L., salt stress, polyphenol, antioxidant activity

Closing remarks

Summary

Helmut Lieth, Brigitte Herzog

Contributions to the 2006 meeting on sustainable utilisation of cash crop halophytes in Tunis

In recent years the utilization of halophytes has received increasing attention. Climate changes, which the senior author predicted some 30 years ago, have in the meantime reached such dimensions that economists, politicians and the general public are now ready to react to this warning given earlier by a few ecologists. The present meeting in Tunis discussed the major topics that the members of International Society for Halophyte Utilization (ISHU) could recommend for action to politicians and to the scientific community. These topics comprised: salinity tolerance types and levels for species of interest; selection of potential cash crop halophytes; genomic analyses; greenification of deserts and Sabkha landscapes; and future research and development topics. Several new points for the halophyte research group were: the discussion of genomic and proteomic analyses and their value for salinity-tolerance improvement of cash crops; the use of satellite remote sensing for the assessment of net primary production (NPP) from the normalized difference vegetation index (NDVI). The classical method to calculate average annual NPP from meteorological and soil fertility data was compared with the correlation of annual NPP values from satellite remotely assessed by NDVI; and the salinity tolerance tests and the multiplication of suitable plants with tissue cultures were explained in greater details.

Keywords: halophytes, desert and landscape greenification, CO_2 -sequestration, salinity tolerance, genomics

Biosaline Agriculture and High Salinity Tolerance

Abdelly, C.; Öztürk, M.; Ashraf, M.; Grignon, C. (Eds.)

2008, XVIII, 370 p. 102 illus., Hardcover

ISBN: 978-3-7643-8553-8

A product of Birkhäuser Basel