Genetic Resources of Rangeland Plants for Extreme Environment Conditions

N. I. Dzyubenko
Russian Academy of Agricultural Science, Russia

The 21st International Grassland Congress / 8th International Rangeland Congress took place in Hohhot, China from June 29 through July 5, 2008.
Proceedings edited by Organizing Committee of 2008 IGC/IRC Conference
Published by Guangdong People's Publishing House

Genetic resources of rangeland plants for extreme environment conditions

N. I. Dzyubenko
State Scientific Centre N.Vavilov All-Russian Research Institute of Plant Industry of RAAS,
St. Petersburg, Russia, e-mail: n.dzyubenko@vir.nw.ru

Key points: rangeland restoration, halophyte plants, rangeland ecosystems

Historically and traditionally, arid rangelands in the Russian Federation and Central Asia have been (and will remain in the foreseeable future) the territories, where beef cattle production, sheep, camel and herd horse breeding keep developing. Prosperity of these branches of cattle breeding and well-being of the peoples inhabiting arid regions of the Commonwealth of Independent States (CIS) including Russia is determined to a significant extent by the state and productivity of natural feeding grounds (rangeland ecosystems).

However, such anthropogenic and technogenic factors as the continuing population growth, high numbers of grazing animals in the past, intensive industrial, mining and irrigational development of arid areas in Central Asia and Russia, have already influenced and keep affecting the soil and vegetation cover and water resources at an increasing rate. Possible ecological consequences for rangeland ecosystems had been ignored and it resulted in their overexploitation, disturbance of normal functioning and degradation.

Under these conditions when the structure of plant communities is disturbed and the environment destabilized, restoration of rangeland ecosystems and their productivity enhancing is an important task of biological and agricultural sciences. This dictates the necessity to use the adaptive approach to the development of biotic principles and methods of ecological restoration of the degraded rangeland ecosystems in arid regions.

The development of biotic principles and methods of the degraded pastures ecological restoration envisages, on the one hand, wide use of biological potential of life forms, species and ecotypes from wild flora, and, on the other hand, of ecological resources and reserves of the arid biome, in order to ensure stability and high productivity of the constructed rangeland ecosystems, as well as their resistance to the unfavourable abiotic and anthropogenic factors that permanently dominate in arid regions of Central Asia and Russia.

Formation of contemporary biocoenoses was accompanied by selection of plant species capable of existing in the environmental conditions showing periodical variation in both annual and diurnal cycles. Each species had developed a living strategy of its own, that is, a combination of adaptations that allowed it to coexist with other organisms and occupy a certain position in the appropriate biocoenosis (Rabotnov, 1983). According to the three types of adaptive strategies identified by L.G. Ramensky (1925), plants have been differentiated into violents, patients and explerents. Similar subdivision was made by D. Grime (1979) and life strategies termed competitive (C), stress-tolerating (**S**) and ruderal (**R**). It was proposed by T. A. Rabotnov (1983) to use terminology of L.G. Ramensky along with letter designations of D. Grime. This proposed concept seems to be quite applicable in the sphere of ecological restoration of the degraded arid pastures.

The violents are the species that develop energetically, occupy and retain a territory, and suppress competitors by the superior vital activity and complete utilization of environmental resources. In the arid zone, these are *Haloxylon aphyllum* (black saxaul), *Haloxylon persicum* (salt tree), *Salsola Paletzkiana*, *Salsola richteri*, *Calligonum caput-medusae*, *Kochia prostrata*, *Artemisia diffusa*, *Poa bulbosa* (bulbous bluegrass), etc.

The patients are the species that manifest tolerance to the extreme environmental conditions and are capable of existing in the conditions that differ from the optimal ones, i.e., under moisture deficiency, or in the conditions of nutritional elements, light or heat deficiency, sometimes under a combination of these factors, or under the influence of other factors limiting plant growth. This type of life strategy in arid regions is implemented by *Salsola orientalis*, *Salsola gemmascens*, *Ephedra strobilacea*, *Camphorosma lessingii*, *Climacoptera lanata*, *Gamanthus gamacarpus*, *Halimocnemis villosa*, *Salicornia herbacea* (jointed glasswort), *Eurotia ceratoides*, *Astragalus agameticus*, etc.

The explerents are the species that have a very low competitiveness, but a good ability to capture the vacated territories quickly. In fact, they fill the temporal and spatial gaps between the violents. This type of life strategy is characteristic of *Bromus tectorum* (cheatgrass), *Eremopyrum orientalis*, *Malcolmia grandiflora*, *Trigonella grandiflora*, *Leptaleum tilifolium*, etc.

Plants of the arid flora typically belong to the group of species that combine properties of both violents and patients. Equally common are the species in which properties of the patients prevail. Introduction and breeding efforts result in selecting forage tree, shrub and semishrub species that combine the traits of violence and patience, and their relative plasticity makes it possible to strengthen each of these traits in the process of establishing stable rangeland ecosystems : 1) violence may be strengthened through a more complete utilization of environmental resources and competitors suppression ; 2) patience-by means of developing the lands unfit for the violents , and 3) explerence may be intensified through a prompt occupation of the areas with a weakened competition , that is , of the disturbed land for a brief period .

A conclusion that follows is of importance for practical restoration of the degraded rangeland ecosystems : if high productivity and stability are the main characters aimed at during creation of rangeland ecosystems in arid zones , then the optimized phytocoenotic balance should be attained through the best realization of different types of life strategies used by the arid flora species in rangeland ecosystems . This may be achieved by stimulating differentiation of ecological niches and by using the complementary traits and properties of plants used for the formation of rangeland communities .

Thus the notions of adaptive strategy types developed by modern biocoenology are of great significance for the theory and practice of arid rangelands management . Violence is a property that plays the main part in ensuring high productivity and maintaining stability of a community , therefore it is of special importance for the improvement of rangeland ecosystems . In this relation , the type of life strategy of a plant , its violence in the first place , should be certainly taken into account when creating perennial rangeland ecosystems in arid regions . At the same time , plant species and ecotypes belonging to the group of patients are no less , or may be even more , important for setting up sustainable rangeland ecosystems in arid regions of Central Asia and Russia . It is obvious , that such specific habitats in arid zones as saline lands and takyrs may be developed into rangeland ecosystems only with the help of forage plants of the patient type .

The plants possessing qualities of explerents (e .g . , gramineous plants , crucifers , legumes , ephemers) can spread out quickly under the conditions of weakened competition . They can be used for creating perennial rangeland ecosystems in the capacity of species complementing the shrub and semishrub communities by means of replacement of layers or successive replacement during the period from sowing through formation of close grass canopy , or during formation of rangeland ecosystem mosaics .

Therefore , the use of adaptive and productive potentials of the ecologically specialized plant species and of rangeland agrobiocoenoses as their systemic formations becomes the most important element of the new paradigm of the agricultural science and practice-of the concept of sustainable agricultural development .

The system of sustainable agriculture is viewed as an ecological complex soil-plant-nature protection-utilization .Acknowledged as a priority trend in the sustainable development system of agricultural production is mobilization (collection) of environmentally specialized plant species , in particular halophytes-plants of saline habitats-for efficient biotic improvement of degraded pastures and saline lands . Halophytes , numbering over 2000 species in the world's vegetation , are capable of normal functioning and reproducing in saline environments . This capability is caused by specific physiological and biochemical properties : increased osmotic pressure of intracellular liquid rising up to 50-80 atmospheres ; ion-transporting systems providing relatively low content of ions in cell cytoplasm ; and C4 photosynthesis .

Analysis and assessment of the data available on ecobiological and economically valuable characters of halophyte plants have shown that these plants include more than 50 species potentially promising for straightaway trials with an aim of domestication and setting up pasture agroecosystems in arid areas (Kurochkina et al . , 1986) .

They include species of the genera *Salsola* L . (saltwort) , *Climacoptera* Botsch . , *Suaeda* Forssk . *ex* Scop . , *Salicornia* L . , *Haloxylon* Bunge (saxaul) , *Tamarix* L . (tamarisk) , *Atriplex* L . (orache) , *Halimocnemis* C .A . May , *Halocharis* Moq . , *Kochia* Roth . (summer cypress) , *Gamanthus* Bunge , *Agriophillum* Bieb . *ex* C .A . Mey , *Bassia* All . , *Glycyrrhiza* L . (liquorice) , perennial species of *Medicago* L . (alfalfa) , perennial arid grasses , etc . When saline , sandy or semi-desert lands are developed , halophytes produce under salt water irrigation 8-15 MT/ha of dry matter , 1 .0-3 .5 MT of seed , and secure production of 1 .5-2 .0 MT/ha of fodder protein . Thus , halophyte plant production with salt irrigation (with sea , collector , drainage or underground waters) may become a prolific source of high-protein and energy-rich feeds and an efficient tool for biotic improvement of the degraded agricultural landscapes .

What task do scientists face in the sphere of halophyte plant production ?
It seems relevant to concentrate attention of researchers involved in halophyte studies and domestication mainly on the following issues :
Collecting plant genetic resources ; accumulating genetic diversity of valuable halophyte species and forms in a collection ; and studying their economic properties for introduction and breeding purposes are certainly relevant . These tasks include the first and vitally necessary phase of work , which would provide sufficiency and effectiveness of halophyte introduction and breeding . An argument supporting the need of a collection with the diversity of valuable halophyte species and forms is the fact that vegetation in the arid areas of Russia is characterized by rich variability of species and ecotypes . Arid regions of the CIS countries harbour over 1200 species of halophyte plants , representing 219 genera and 34 families (Z .S . Shamsutdinov & N .Z . Shamsutdinov , 2005) .

These species demonstrate different degrees of halotolerance. The scope of mineralization in a soil solution, within which this or that plant can normally grow, varies with different species: hyperhalophytes-plants of excessively saline soils; euhalophytes-plants with a large scope of tolerance to mineralization of a soil solution; hemihalophytes-plants of moderately saline soils; and haloglycophytes-plants with rather small salt resistance.

Preliminary analysis of the existing floristic, pasture-related geobotanical and ecological publications has shown that there are more than 100 halophyte species of potential interest for introduction and breeding improvement for halophyte plant production purposes (Dzyubenko et al., 2007). In view of this, it is necessary to carry out systematic collecting of halophytes seed samples in arid areas of Russia and adjacent countries, set up collection nurseries, study ecological properties of the collected materials, and select high-yielding salt-resistant species and forms from wild populations for plant and feed production purposes.

Combination of bioecological and economically valuable characteristics may serve as a basis for evaluating and selecting against the background of salt water irrigation such halophyte species and forms that would possess high fodder and seed productivity.

Studying ecophysiological and biochemical features; developing methods for assessing productivity, drought-and salt-resistance; constructing morpho-physiological models of halophyte cultivars for cultivation under salt water irrigation (with sea, collector, drainage or underground waters) and biotic improvement of degraded rangelands-that are the main directions of research work now.

Introduction of wild halophytes into cultivation by producing cultivars and using sea water for irrigation requires solving a whole series of ecophysiological issues, beginning from structural and functional organization of assimilating organs, initial CO_2 fixing processes, kinetics of minerals in the plant-substrate system, response of different species and ecotypes to irrigation, their adaptive and productive potential, and ending with development of the principles enabling ecophysiological optimization of plantings for more complete implementation of bioclimatic potential in the areas of halophyte cultivation.

Considering insufficient knowledge of ecobiological and physiogenetical nature of halophytes, absence of practical experience in their cultivation, and unconventionality of farming for the desert zone, an important requirement for their successful domestication and cultivation for plant production and forage production purposes is complex examination of their ecology, physiology and biochemistry of all levels-from organismal to phytocoenotic. These issues are one of the most vital aspects of successful solving the problems of halophyte plant production.

Breeding ecologically differentiated cultivars of pasture halophytes, capable of yielding 8.0-15/0 MT/ha of dry matter under salt water irrigation and suitable for biotic improvement of rangelands-that is the main aim.

Vast territories in the arid zones of the CIS with saline, takyr-type, dry and sandy soils may be effectively reclaimed into high-yielding pasture agroecosystems by developing fundamentally novel and ecologically specialized cultivars with high resistance to extreme environments and capability to tolerate salinity and drought. Genetic sources for selecting species and breeding ecologically specialized cultivars are halophytes and haloxerophytes of natural arid vegetation. Halophytes often contain an increased quantity of salts, and sometimes alkaloids, which make them seasonally inedible or poorly suitable for feeding animals. There is no evidence how irrigation, especially with salt water, may influence the productivity of halophytes and the quality of plant products. All this calls for the need to organize research works in plant breeding and seed production of promising pasture halophytes.

References

N.I. Dzyubenko, L.L. Malyshev & N.Z. Shamsutdinov. Specific diversity of halophytes as an important genetic resources for developing salt-resistant cultivars of forage plants. In: Crop Genetic Resources in the 21st Century: Current Status, Problems and Prospects. VIR, St. Petersburg, 2007, 65 pages.

J.P. Grime. Plant strategies and vegetation processes. New York: John Wiley, 1979, 222 pages.

L.Y. Kurochkina, L.T. Osmanova & K.N. Karibaeva. Forage plants of Kazakhstan deserts. Alma Ata, 1986, 208 pages.

T.A. Rabotnov. Phytocoenology. MSU, Moscow, 1983, 296 pages.

L.G. Ramensky. Introduction into complex soil science and geobotany land research. Moscow, 1925, 620 pages.

Z.S. Shamsutdinov & N.Z. Shamsutdinov. Halophyte plant production. Moscow, 2005, 404 pages.