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IMPROVEMENT OF SALT TOLERANCE IN CROPS

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Soil salinity is one of the major obstacles to crop production in arid and semi – arid regions. To overcome this problem scientists have devised various reclamative methods and management practices. But under these circumstances biological approach in conjunction with management practices, seems to be a highly efficient way of overcoming the salinity menace. The present paper outlines the achievements gained through biological approach in the past few years. The implications of selection and breeding for salt tolerance, in particular, have been highlighted.

INTRODUCTION

Environmental stresses such as salinity, waterlogging, drought, and high temperature are serious threat to agriculture in Pakistan. For instance, only salinity has devastated about 14 million acres of arable land in the country. This is really a challenge for our agricultural scientists. Soil scientists have devised various reclamative and management measures to make the salt – affected land fit for agriculture. But these methods are extremely expensive while the biological approach of overcoming salinity stress has recently gained recognition.

There is, much evidence available in the literature that evolution in nature is the outcome of natural selection working on the genetic variability in natural populations of species. It is also evident that gene frequencies are altered by selection, and new gene combinations favoured by selection because of their great adaptation to the changed environmental conditions. This is the way how species evolve to exist as a number of adapted populations. For example salt tolerant populations of many species have been found on highly salt affected soils, salt marshes and sea cliffs etc. These populations are certainly the outcome of natural selections.

With artificial selection, man, in stead of nature, acts as the agent of selection and a rapid improvement in a character is achieved. It is important to examine the way in which artificial selection has, in conjunction with improved cultural practices, improved crop yields (see Poehlman, 1986, Silvey, 1981, Woodwarth et al, 1952).

It is notable that such achievements entirely relied upon assessment of the phenotypic expression of the features involved and details of the underlying physiological mechanisms producing those phenotypes were not clearly known. A quite similar approach has been used with remarkable success in the past to distinguish between salt tolerant and salt sensitive plants (Kingsbury & Epstein, 1984).

Different approaches for detection and exploitation of useful variation.

The basic features of evolution in natural conditions and under domestication are the same; both involve two basic steps. i) there must be genetically stable variation for the desired character in a population; ii) there must be selection of those individuals possessing the best expression.

Plant breeders, however, have adopted the following different strategies to explore useful variation so as to improve salt tolerance in important crop species.

1. Screening of local / exotic germplasm-Intercultivar variation.

Local / exotic accessions available, as many as possible, of different crop species have been screened, and the most tolerant accessions multiplied either for further selection or for direct use on salt – affected soils. For examle, Dewey (1960, 1962) evaluated 25 and 60 strains of Agropyron desertorum, respectively for their ability to survive at different salt concentrations and found very few strains relatively tolerant. Shannon (1978) working with another species of Agropyron, A. elongatum, screened 32 accessions at a range of salt treatments. He identified only 7 out of 32 accessions that were highly tolerant. Qureshi et al (1980) found considerable variation in salt tolerance in a small number of spring wheat varieties. They identified three out of 12 cultivars / lines that were relatively highly salt tolerant at different growth stages.

Similarly, Kingsbury & Epstein (1984) screened 5,000 accessions of spring wheat and found only a few tolerant that survived and produced economic yield at high salt concentration. Azhar & McNeilly (1987) examined considerable variation in a sample of 51 accessions of Sorghum bicolor using only a single selection criterion i.e. root length, that has been previously used by many workers for screening grasses for salt tolerance (Ahmad & Wainwright, 1977; Venables & Wilkins, 1978; Wu, 1981; Ashraf et al, 1986). Recently Ashraf & Waheed (Unpublished data) have screened 133 accessions of lentil and identified only 5 lines that are highly tolerant to NaCl.

2. Screening of variable material of a single cultivar– Intravarietal variation.

Large numbers of genotypes from genetically variable material of either naturally outcrossing species or produced by artificial crossing have been screened and very few tolerant individuals identified. Epstein & Norlyn (1977) achieved a significant improvement in salt tolerance of barley after a single cycle of selection. The selection was carried out on variable material from a composite cross. The selection lines were so tolerant that they survived till maturity and gave reasonable seed yield under irrigation with undiluted sea water. Salt tolerance in an alfalfa (Medicago sativa L.) cultivar was increased through recurrent selection at the adult stage (Noble et al 1984). Similarly salt tolerance of the same species at the germination stage was improved after 5 cycles of mass selection (Allen et al, 1985). In quite parallel studies Ashraf et al (1986, 1987) screened 10,000 –20,000 seeds of variable material of 7 grass and 4 leguminous species i.e. the selection intensity was less that 1% in all cases. The progeny of the selected tolerant lines produced remarkably greater biomass at different salt concentrations as compared to their respective unselected base populations. Al –Khatib (unpublished data) using the method of Ashraf et al (1987) has improved the salt tolerance of an alfalfa cultivar through recurrent selection at the seedling stage. He has also observed considerable useful intracultivar variation in alfalfa.

Maize has been categorised as moderately salt sensitive as compared to other crops (Maas & Hoffman, 1977) . Salt tolerance of this crop was improved by screening 10,000 seeds of a salt sensitive cultivar, Akbar at 180 mol m^{-3} NaCl in nutrient solution (Ashraf & McNeilly, 1990) The progeny of the salt tolerant selection line produced significantly greater biomass than the unselected base population when tested in a range of NaCl concentrations.

3. Interspecific hybridization.

Salt tolerance of some crop species have been enhanced by transferring genes from highly tolerant wild relatives to cultivated species by conventional breeding techniquies. An attempt in this regard was made by Rush & Epstein (1981) who first of all assessed the salt tolerance of the wild Lycopersicum cheesmanii collected from Galapagos Islands and the cultivated L. esculentum and found the former relatively highly salt tolerant. Fortunately, the two species were interfertile. However, they were bred and some highly tolerant plants were selected from the F_2 progeny, which had also acceptable fruit size as compared to that of the wild bearing tomatoes normally about 1 cm in diameter.

4. Intergeneric hybridization

Attempts have been made to hybridize spring wheat with a highly salt tolerant grass, Thinopyrum bessarabicum (Foster et al. 1987) and the resultant hybrid was significantly more tolerant than the wheat parent. At the Nuclear Institute for Agriculture and Bology Faisalabad a scientist has claimed successful hybridization between, Leptochloa fusca and rice.

Criteria for selection

Plant physiologists/biochemists have recommended many selection critaria for salt tolerance such as proline, betaine, glycinebetaine, pinitol, sugar accumulation, Na/K or Na/Ca ratios etc. But these parameters do not show any consistent relationship with salt tolerance in different crop species, because physiological mechanism may vary from variety to variety (Greenway & Munns, 1980).

For characters like salt tol erance or drought tolerance which are controlled by many genes, the understanding of physiological mechanisms of tolerance is very complex. However, for heavy metal tolerance root length differences have been widlely used as a reliable selection ciriterion to distinguish between heavy metal tolerant and sensitive populations and even to distinguish between individuals within a population (Bradshaw & MCNeilly 1981)

Root length differences have also been used with considerable success to select for salt tolerance in many grass species (Hannon & Bradshaw, 1968; Ahmad & Wainwright, 1977; Venables & Wilkins, 1978; Khan & Marshall, 1981; Wu, 1981; Ashraf et al, 1986, 1989) . But the root growth did not prove to be successful criterion in some leguminous species by Ashraf et al 1987) where they screened large number of seedlings on the basis of shoot length differences. In contrast, Ab-Shukor et al (1988) have successfully distinguished salt tolerant and salt sensitive natural populations of Trifolium repens on the basis of root growth tests. In some other crops it was established that selection criterion based on the basis of whole plant performance would be appropriate for selecting for salt tolerance such as in rice (Akbar et al, 1986), millet (Ashraf & McNeilly, 1987), and wheat Ashraf & McNeilly, 1988).

Characters such as heavy metal tolerance, drought tolerance and salinity tolerance have been considered as quantitative characters. However, the study of genetic basis of a quantitative character depends on the study of its variation. The magnitude of variation is measured and expressed as variance.

The values of narrow-sense heritability tells us what proportion of the phenotypic differences are additive genetic in origin and how much resemblance does exist between parents and offspring. This is the parameter which a plant breeder requires to evaluate his breeding material. If the value of h^2N is high for a character, considerable rapid success for its improvement is possible through selection .

Despite considerable practical importance of genetical studies on salt tolerance of cop species very little work has been done in the past on this aspect. Before 1986 there are, in the literature, very few references concerned with gentic aspects of salt tolerance. However, Dewey (1962) salt estimated gentic variation in salt tolerance in 60 strains of crested wheat grass and suggested that due to great magnitude of variation remarkable improvement in its salt tolerance could be achieved through recurrent selection. Similarly Abel (1969) was able to show that Cl^- exclusion in soybeans is genetically determined and is controlled by a single gene. Hunt (1965) showed that salt tolerance in Agropyron intermedium was considerably heritable with a parent - progeny correlation coefficient (r) of 0.83. Genetic studies conducted on rice (Akbar, 1973) have shown that F_1 hybrids of tolerant x tolerant and tolerant x sensitive cultivars have significantly higher tolerance than their respective parents.

The salt tolerance in alfalfa was also shown to be highly heritable ($h^2 = 0.41$) by Noble et al (1984) when plants of a single cultivar were selected at the adult stage in high salt concentration. In the same crop Allen et al (1985) have improved the salt tolerance at the gemination stage through recurrent selection and found this character highly heritable, since the broad -sense heritability in a range of grass and lengumi-nous species. The heritability estimates were obtained from female parent - progeny regression and realised heritability and the values in all species were quite high. The data for heritability suggested that improvement in salt tolerance could be obtained through further selection and breeding in all the species examined.

CONCLUSIONS

It is now quite clear that variation in salt tolerance does occur in crop species and this variation, at least in part is heritable. The extent to which the variability is heritable, is also considerably high. These features clearly support the evidence that considerable improvement in salt tolerance could be achieved through repeated cycles of selection. But for a successful selection a few points should be contemplated. Firstly, selection pressure should be very high because this may eliminate all the salt sensitive individuals from a variable population. Secondly, with the imposition of high selection pressure, it would be possible to select very few individuals with considerably high tolerance. In other words the selection intensity should be as low as possible. Experience to date shows that selection intensity less that 1% has proved successful to separate highly salt tolerant lines of several crop species. Thirdly, large numbers of plants, as many as possible, should be screened. The author has been able to select upto 30,000 seeds of some species and has developed highly salt tolerant lines.

Crop yield improvement though selection and breeding in relation to salinity stress is of great economic value .

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