Benefits and limitations in breeding salt-tolerant crops

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Some crops, such as cotton, barley, safflower, or sugarbeet, can be grown in relatively saline soils; others, including beans and corn, can be grown only in nonsaline soils. It is intriguing to speculate that a sensitive crop plant might be genetically altered to withstand high salinities. Breeders have considered this approach for many years, but research along these lines has been neglected in favor of other problems. Instead, management options have been used to alleviate saline conditions and, during reclamation of salt-affected soils, farmers have limited their choice of crops to the more tolerant species.

Yet it seems feasible to select the survivors or the plants that perform well from a crop grown in a saline environment, and thus improve salt tolerance. Varieties within some crop species show rather large differences in ability to grow under saline conditions. The genetic potential to improve crops exists, but there are limitations that until now have prevented the development of salt-tolerant varieties among sensitive crop species.

Salt-tolerant species cannot substitute for good management practices that prevent salt accumulation in the soil. Such species can be valuable, however, for cropping saline soils that are undergoing gradual reclamation or that cannot be fully reclaimed because of limited natural or economic resources. Tolerant species can also be useful where good quality water is not available. Consideration could be given to developing crops that are productive when grown with saline irrigation waters, such as brackish underground well water, drain water, or even diluted sea water. It may be possible to improve the genetic tolerance of crops to salinity and thereby increase the productivity of marginal lands. The major roles for salt-tolerant species may be to improve yields and uniformity of crops now grown in naturally salt-affected areas, to increase the types of crops that a farmer in a salt-affected area can grow, or to provide crops suited to marginal areas with limited water resources.

Salinity may affect crop quality as well as yield. In lettuce, it can reduce head formation. Top row is unselected parental line; middle row was selected for better head formation, bottom row for high yield without regard to heading.

Salt-affected fields are extremely variable in salinity. In different portions of the field, the productivity of a crop can vary from 0 to normal, but total yield is decreased. A grower may strive to reduce the overall salinity level through good management, but no doubt there will always be some saline spots. Salt-tolerant crops could be useful for these situations.

Excessive salt acts as an environmental stress, decreasing a plant's growth potential. The extra energy that the plant exerts in resisting the stress reduces growth and yield. Breeding for salt tolerance can be thought of as selecting plants that withstand salt stress most effectively. All crop plants have physiological limits to salt concentration. Concentrations above a certain threshold will reduce crop yields or cause death. In theory, salt tolerance may be improved by increasing this threshold or by decreasing the sensitivity to salt beyond the threshold.

The plant breeding approach to producing salt-tolerant crops has two limitations — limited sources of genes for salinity tolerance and lack of rapid, precise evaluation methods. Genetic variability among U.S. cultivars may be more limited than among world collections, or among close relatives of crop plants. This variability can be seen in the responses of 33 lettuce cultivars compared with those of 31 plant introductions and 32 collections of related species.

Genetic resources for breeding have typically been selected from the best materials within the crop species, but there may be many sources of tolerance in wild relatives of crop plants. An example is the wild tomato, *Lycopersicon cheesmanii*, collected in the Galapagos Islands by C. M. Rick of the University of California, Davis; this species hybridizes easily with cultivated tomato, *L. esculentum*, and appears to be an excellent source of tolerance to salinity. Similar results may apply to wheat in research by J. Dvorak and his associates at UC Davis using tall wheatgrass, *Elytrigia pontica*, as a source of genes to be transferred to wheat.

The choice of methodologies to screen for salt tolerance depends to some extent on the targeted production system and the crop itself. Plant response to salinity differs at various stages of the growth cycle. For example, some crops can germinate under high salinities but grow poorly thereafter; for others, the reverse is true. High salinities at the reproductive stage can cause sterility in some species and lead to significant yield loss. Research on a number of crops now being conducted at the U.S. Salinity Laboratory in Riverside will help breeders determine at which growth stage a species is most susceptible to salinity in its particular cropping system. From such data, appropriate evaluation or screening procedures can be developed.

Ultimately, breeders may be able to develop simple evaluations based on the physiological mechanisms for salt tolerance. Some tolerant plants accumulate ions such as sodium in leaves and other tissues; others have ways of preventing ions from entering the plant. These two mechanisms may have important effects on salt tolerance. Breeders are hopeful that simple evaluations for the presence/absence or high/low levels of ions or other osmotically important chemical compounds in plants can be developed that will indicate salt tolerance. Osmoprotective compounds,such as those identified in bacteria, are present in plants and may offer an opportunity for breeders in the future. Currently, however, not enough is known about the physiological mechanisms of salt tolerance to make this approach practical.

At UC Davis, Emanuel Epstein and co-workers have identified salt-tolerant cereals (barley, triticale, and wheat) and tomatoes by growing them in salinized solution-tank cultures throughout their entire life cycles. A plant must germinate under high salinity (50 to 75 percent the salinity of seawater) and grow to maturity to be considered salt tolerant. By this method, they identified salt-tolerant wheats, including varieties with known salinity tolerance such as Kharchia from India. The next step was to evaluate the selected materials in a number of California field sites with natural salinity gradients. Each barley or wheat entry was subjected to a wide range of salinity, and its performance compared with that of control varieties. A response curve was obtained by measuring yields obtained from locations differing in soil salinity.

Surviving varieties of wheat growing in water half as saline as sea water will be tested in the field in search for high-yielding, salt-tolerant strains.

Some of the best entries from the tank cultures did quite well in the field, but others did not. Some of the standard salt-sensitive, high-yielding varieties produced so well at low salinity that their productivity in a variably salt-affected field would be greater than that of a lower yielding, salt-tolerant type. The goal now is to produce varieties with both high yields and salt tolerance.

The high variability of natural gradients in fields makes it difficult to obtain precise data for variety comparisons. Controlled salinity in field conditions would be much more suitable for the breeder. U.S. Department of Agriculture workers have developed facilities at the Irrigated Desert Research Station in Brawley and Riverwest Farms at Lost Hills that are ideally suited to evaluations of materials for breeding purposes and will be used in the next phase of breeding.

Crop quality may be as important a consideration as yield in developing salt-tolerant plants. It has long been known that salt increases the amounts of osmotically active substances in plants. For instance, sugar content may increase in plants that generally try to exclude salt. Sugarbeet and muskmelon grown in saline soils have higher sugar contents than those grown in nonsaline soils. Higher soluble solids have also been reported in tomatoes derived from crosses between the salt-tolerant *L. cheesmanii* and the cultivated variety. In this instance, increased salt concentration in the fruit may also be contributing to higher soluble solids content. Plants that accumulate salt usually have higher tolerances than plants that do not, but high salt content may not be desirable for humans and animals. Potential toxicities of salinity-induced accumulations of osmotically active substances have not been examined thoroughly.

Salinity may also affect quality, for instance, by reducing head formation in lettuce and decreasing storage life in some fruits. Such problems can be corrected by plant breeding. At the U.S. Salinity Laboratory, selections of lettuce from the cultivar Empire have shown tolerance to salinity and resistance to the tendency toward poor head development at high salt concentrations.

Breeding salt-tolerant crops requires consideration of (1) the technical aspects of genetic manipulations, (2) the interactions between salt tolerance and management of soil and water, and (3) the effects of salt on food and feed quality. The major problem for the breeder is to combine the good agronomic characters of present varieties with the salt tolerance of unadapted introductions. Results already obtained with the tomato show that this approach is feasible and can be obtained using conventional plant breeding methods.

Just as growers have developed management strategies to cope with salinity, plant breeders must fine-tune varieties of many crops to fit specific agroecological niches. It now appears that, at least in some crops, salt tolerance should have a high priority among the problems for breeders to solve.

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