Salt tolerance in chickpea: Towards an understanding of sensitivity to salinity and prospects for breeding for improved resistance

by Timothy D. COLMER[1]* and Vincent VADEZ[2]

Abstract: Chickpea (*Cicer arietinum* L.) is sensitive to salinity, although genotypes showsignificant variation in tolerance. The reproductive phase appears to be particularly salt-sensitive.Importantly, recent screening experiments have been conducted to maturity with evaluation of seed yield under saline conditions, The genetic variation appears to be sufficient to breed for improved salt tolerance, but heritability of tolerance requires further study, only minor QTLs for salt tolerance have been identified, and the physiological basis of genotypic differences in tolerance is unclear; so, screening and selection of progeny will likely be a bottleneck in improvement of salt tolerance in chickpea.

Key words: *Cicer arietinum*, NaCl, ion toxicity, soil salinity, water relations

Soil salinity is a major stress factor that restricts crop yields in many parts of the world(4). Salinity continues to increase in many regions, affecting previously productive land in dryland and irrigated farming systems, and especially in areas where total annual evaporation is high. Chickpea is sensitive to salinity – this sensitivity is very evident when chickpea is compared to other species in cropping systems, for example bread wheat.

The impacts on chickpea of salinity have been reviewed (1). Salinity impacts on germination, plant establishment, nitrogen-fixation, vegetative growth, flowering, podding and seed filling; but the sensitivity to salinity differs between these processes/stages and in various genotypes. Germination appears relatively more salt tolerant than vegetative growth, but with the reproductive phase being particularly salt-sensitive (1, 6, 7).

The adverse effects of salinity on plants (3) are usually considered in terms of the impact of excess ions in the soil on plant water relations (i.e. the 'osmotic effect' of salinity) and of high tissue ion concentrations, typically Na^+ and/or Cl^-, resulting in tissue injury (i.e. 'ion toxicity'). In addition, the disruption by high Na^+ of plant K^+ and Ca^{2+} homeostasis also contributes to the adverse effect of salinity on salt-sensitive species.

Salinity reduces the amount of water that chickpea crops can extractfrom soil, causing water deficits and also limiting carbon capture and therefore growth and yield (1). In addition, the build-up of ions in leaves can result in necrosis, but whether high tissue Na^+ or Cl^- (or both) cause the damage is unclear, and tolerance is only sometimes correlated with differences in tissue ion concentrations (1). For example, differences in seed yield under saline conditions among a large and representative set of germplasm was not related to differences in shoot tissue Na^+ concentration (7). Whether genotypes differ in 'tissue tolerance'should be explored; the term 'tissue tolerance' is used by us to meanthe maintenance of functional tissues (e.g. capacity for photosynthesis) despite high internal Na^+ and Cl^- concentrations.

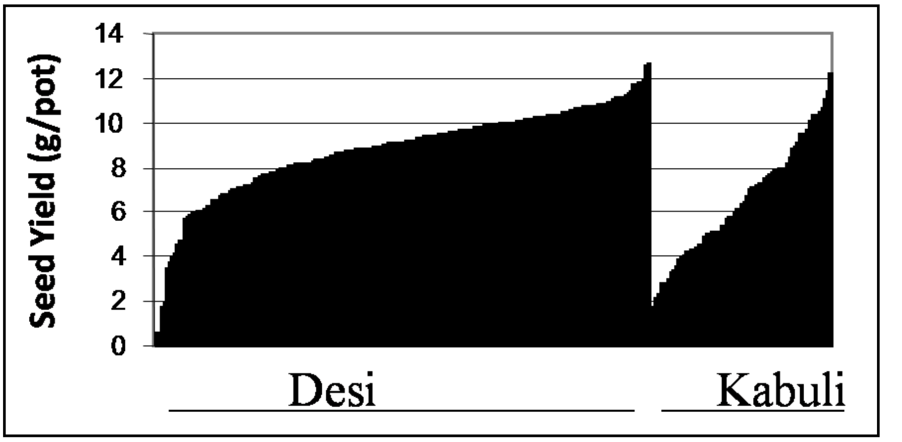

Figure 1. Seed yield under saline conditions in a large and representative range of chickpea genotypes. The figure shows large variation in both Desi and Kabuli types, although overall, the Kabuli types had lower seed yields in the saline soil (1.17 g NaCl kg^{-1} soil) than the Desi types. Experiment conducted in an outdoor pot system at ICRISAT. For more, see (7).

[1]The University of Western Australia, School of Plant Biology and the Institute of Agriculture, Crawley, Australia (timothy.colmer@uwa.edu.au)
[2]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India

In addition to the effects on chickpea (1) from the osmotic and specific-ion components of salinity stress (3), salinity can cause large reductions in nodulation, nodule size and nitrogen-fixation capacity (1). The resulting lower nitrogen status caused by a dysfunctional rhizobium-plant symbiosis under saline conditions would likely add to the lesions already discussed above for chickpea when exposed to salinity, and further restrict growth and yield in saline soils.

Effort to breed more salt tolerant varieties of chickpea has been limitedto date, although selections with reasonable salt tolerance (for chickpea) have been released (e.g., KarnalChana 1 or CSG8962 in India). Several studies have highlighted diversity in salt tolerance within chickpea (2, 7) and importantly large variation in seed yield (per plant) in saline soils has been demonstrated (7, Fig. 1). Among chickpea genotypes, there is considerable variation in seed yield in saline soils for both desi and kabuli types, but the kabuli types are generally more salt-sensitive than the desi types (Fig. 1). Although there is genetic variation for salt tolerance in chickpea, knowledge of the genetic and physiological basis of the differences between genotypes is poor, hampering parental selections for possible pyramiding of key traits as has been proposed for breeding of salt tolerance in rice (10).

The reproductive stages appear to be particularly sensitive to salinity. A recent large scale screening for yield under salinity showed that tolerance, i.e. high yield under saline conditions, was related to the capacity of maintaining and filling a large number of pods (7, Fig. 2). The photographs show two genotypes with similar vegetative growth in saline soil, but with very different reproductive success in these saline conditions (Fig. 2). To date, only minor QTLs for salt tolerance have been identified in chickpea (8), being consistent with results of a genetic analysis which revealed the complex regulation of salt tolerance in chickpea (5). However, a few QTLs with substantial effect on traits related to yield under saline conditions, such as the number of pods and therefore seeds per plant, have been identified (8).

Additional research is needed, therefore, to develop efficient screening and selection techniques of progeny (e.g., based on phenotypic traits, possible marker-assisted selection, and ultimately grain yield in saline conditions). Screening strategies should focus on traits which contribute to high yield in saline soils. Difficulties in screening and selection are further heightened by the typically large variability in soil salinity in fields. Recently, it was found that yield in saline soil was related to the capacity of producing more flowers and to a high number of tertiary branches (9). These traits were identified both under saline and non-saline conditions, pointing to constitutive traits being important for yield in saline soils. A priority will also be to understand the basis of the sensitivity of reproduction to salinity. Moreover, as reproduction is sensitive to other stresses, such as drought, our on-going work will evaluate the possibility of reproductive stage tolerance mechanisms being beneficial across stresses.

The need for crops with improved salt tolerance, including the gains likely if the high sensitivity of chickpea to salinity can be overcome, means the challenges towards improvement of salt tolerance in chickpea should be of priority for future research. ■

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Figure 2. Photographs of a tolerant (left) and a sensitive (right) genotype of chickpea when grown in saline soil (1.17 g NaCl kg^{-1} soil). The picture shows similar vegetative development but large differences in the number of pods between the tolerant and the sensitive genotypes. Both genotypes produced pods by this stage in the non-saline controls. Experiment conducted in an outdoor pot system at ICRISAT. For more, see (7).