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Abstract: Seeds of 4 cultivars of chickpea (2 desi, CSG 8962 and DCP 92-3, and 2 kabuli, CSG 9651 and BG 267) were grown under 0, 4, 6 and 8 dS m^{-1} levels of salinity until maturity. Shoot and root dry weights, root shoot ratio and various yield parameters were evaluated under salinity at 40, 70 and 100 days after sowing. Salinity significantly reduced dry matter accumulation in both roots and shoots in all cultivars, though declension was more pronounced in BG 267 (kabuli) and DCP 92-3 (desi). Root growth was more adversely affected than shoot growth, which also had an impact on the root to shoot ratio. Negative effects of salinity on plant growth had an ultimate effect on ultimate plant productivity. CSG 9651 showed high levels of tolerance compared to the other cultivars. The results suggest that chickpea cultivars tolerant of salinity have better growth potential and ultimately higher yield than do sensitive ones.

Key Words: Chickpea, root to shoot ratio, growth, salinity, tolerance, yield

Introduction

Soil salinity adversely affects plant growth and development. Worldwide, about one-third of irrigated arable land is already affected and that level is still rising (Lazof and Bernstein, 1999). An excess of soluble salts in the soil leads to osmotic stress, which results in specific ion toxicity and ionic imbalances (Munns, 2003), and the consequences of these can be plant demise (Rout and Shaw, 2001).

Increasing crop salt tolerance is a highly attractive approach to overcoming the salinity threat. The need of the hour is to explore and select salt-tolerant genotypes within a species in comparison to relatively salt-sensitive ones through conventional selection and breeding techniques.

Chickpea (*Cicer arietinum* L.) is a major food legume and an important source of protein in many countries. In addition, it is also widely used as fodder and green manure. Chickpea seeds contain 20.6% protein, 2.2% fat and 61.2% carbohydrates (Gupta, 1987). Cultivars grown in India are either native (desi) types or Mediterranean (Kabuli) types (Van der Maesen, 1987). However, chickpea is highly sensitive to salinity, like many other leguminous crops (Ashraf and Waheed, 1993). Therefore, identifying sources of tolerance to salinity will be of great practical importance. Since chickpea is indigenous to arid areas, it may have a degree of adaptation to various environmental stresses. It thus offers a valuable germplasm for breeding purposes and for the determination of more tolerant cultivars that give minimum depression in yield when grown in saline soils and may be an efficient tool tin resolving the salinity problem to some extent. There have been studies on the effects of salinity on nodulation and nitrogen fixation (Elsheikh and Wood, 1990; Soussi et al., 1999; Rao et al., 2002). However, comparative accounts of desi and kabuli chickpea are rare. This investigation was thus undertaken with the aim of assessing the effect of a continuous supply of salinity on plant growth and plant productivity in desi and kabuli chickpea cultivars.

Materials and Methods

Seeds of *Cicer arietinum* L. cultivars, i.e. DCP 92-3 and CSG 8962 (desi) and BG 267 and CSG 9651 (kabuli) were obtained from the Central Soil Salinity Research Institute (CSSRI), Karnal, India. Seeds were inoculated

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with salt-tolerant *Mesorhizobium ciceri* strain F: 75 procured from IARI, New Delhi. Seeds were surface sterilised in 30% (w/v) mercuric chloride for 2 min, rinsed with sterile water and germinated in pots lined with polythene bags. Each pot was filled with a mixture of thoroughly powdered soil, sand and farmyard manure in proportion of 2:2:1 by volume. The pots were treated with saline solutions (prepared from a mixture of sodium chloride, calcium chloride and sodium sulphate in a ratio of 7:2:1) of various electrical conductivity levels i.e. 0, 4, 6 and 8 dS m^{-1}. The soils were supplemented with these salt solutions on 3 consecutive days before sowing in order to obtain the required salinity level. The desired salinity levels were maintained throughout the growing period of the crop by fortification with saline solutions at regular weekly intervals. The electrical conductivities of different salinity levels were adjusted on direct conductivity meter readings. The control sets were irrigated with tap water only. Three plants of uniform size were maintained in each pot. Plants were sampled and analysed for the following parameters at different growth stages: 40, 70 and 100 DAS. Two pots with 3 plants in each were sampled per treatment.

Shoot and root dry weight: The shoot and root dry weights of plants were taken after drying the samples in an electric oven for 72 h at 70 °C at 3 different growth stages, namely 40, 70 and 100 days after sowing (DAS).

Root/shoot ratio: This was calculated for weights by dividing root values by shoots.

Yield attributes: With the onset of flowering, 6 uniform plants under each treatment were marked for recording the number of flowers produced at 2-day intervals. At harvest, the same plants were used for recording observations on the number of pods, number of seeds per plant, seed weight per plant, 100-seed weight and total plant dry mass. The harvest index was calculated by dividing seed weight per plant by total plant dry weight.

All the values are means of 6 replicates per treatment and the data were analysed statistically with a least significant difference (LSD) between means.

Results and Discussion

That salinity reduced the plant growth irrespective of the cultivar is evident from the decline in dry weights of both roots and shoots with increasing stress (Figures 1a,b). As stated by Munns (2003), suppression of plant growth under saline conditions may either be due to the decreasing availability of water or to the increasing toxicity of sodium chloride associated with increasing salinity. The root weights showed a higher decline than did the shoot weights in all the cultivars and at all stages of growth. The reduction in root and shoot dry weights directly affected the root to shoot ratio (RSR), which also declined with salinity (Table 1). The changes in growth were visible at the lowest salinity level and became more pronounced at the highest saline level of 8 dS m^{-1}. The effects were more severe in DCP 92-3 than in BG 267, CSG 8962 and CSG 9651. Decreases in root and shoot weights have been already reported for desi chickpea (Elsheikh and Wood, 1990; Soussi et al., 1998). The reduction in dry weight under salt stress may be

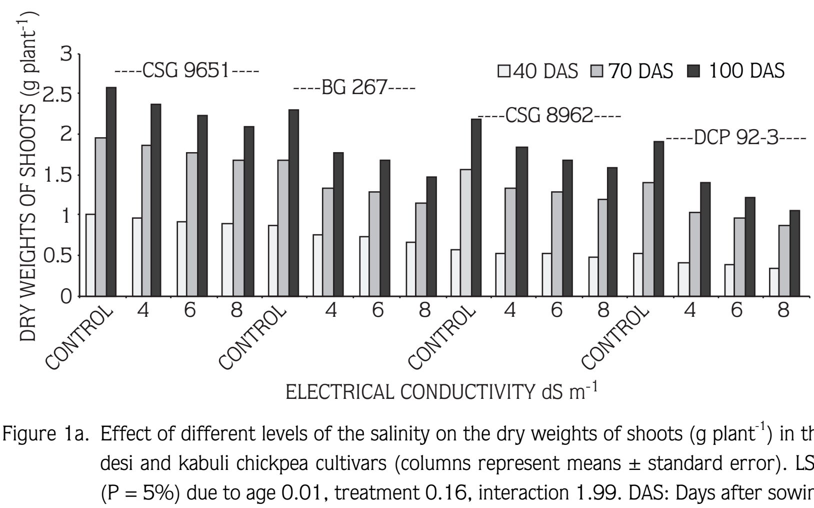

Figure 1a. Effect of different levels of the salinity on the dry weights of shoots (g $plant^{-1}$) in the desi and kabuli chickpea cultivars (columns represent means ± standard error). LSD (P = 5%) due to age 0.01, treatment 0.16, interaction 1.99. DAS: Days after sowing

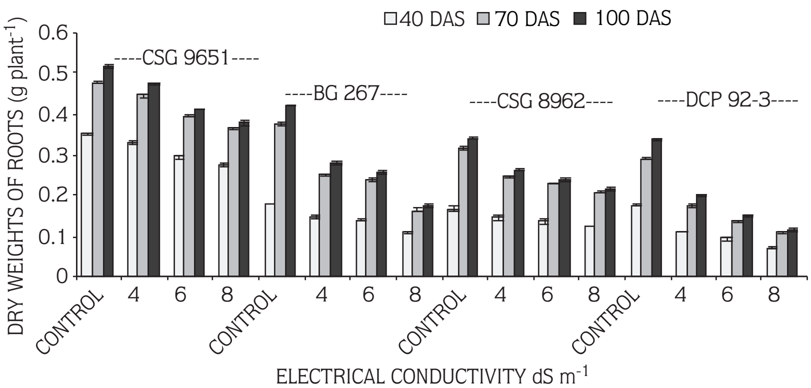

Figure 1b. Effect of different levels of the salinity on the dry weights of roots (g $plant^{-1}$) in the desi and kabuli chickpea cultivars (Columns represent means ± standard error). LSd (P = 5%) due to age 0.03, treatment 0.06, interaction 1.43.

Table 1. Effect of different levels of salinity on the root to shoot ratio (RSR) in the desi and kabuli chickpea cultivars. DAS: Days after sowing

		SOIL SALINITY (dS m^{-1})		
DAS	CONTROL	4 dS m^{-1}	6 dS m^{-1}	8 dS m^{-1}
		CSG9651 kabuli		
40	0.350	0.343	0.316	0.306
70	0.245	0.233	0.222	0.216
100	0.201	0.191	0.180	0.178
		BG267 kabuli		
40	0.226	0.224	0.218	0.171
70	0.198	0.164	0.163	0.114
100	0.181	0.156	0.151	0.112
		CSG8962 desi		
40	0.311	0.292	0.286	0.274
70	0.200	0.185	0.178	0.172
100	0.155	0.144	0.140	0.136
		DCP92-3 desi		
40	0.338	0.258	0.248	0.209
70	0.206	0.168	0.140	0.128
100	0.175	0.162	0.121	0.110

LSD (5%) due to age 0.16, treatment 0.54, interaction 0.93

attributed to inhibition of hydrolysis of reserve synthesising food and its translocation to the growing shoots (Singh et al., 2001). Hence, reduction in shoot dry mass with a decline in root mass was a normal growth reaction. Shoot growth is a complex phenomenon and several factors other than reduced root growth are involved. According to Cheeseman (1988), salinity stress imposes additional energy requirements on plant cells and diverts metabolic carbon to storage pools so that less carbon is available for growth.

Negative effects of salinity on plant growth had a direct effect on ultimate plant productivity (total plant dry mass accumulation, grain yield, harvest index etc.) (Table 2). The intensity of flower production was progressively reduced by increasing levels of salt stress, irrespective of the type of cultivar. The reduction in flower production was highly prominent in DCP 92-3 (desi) compared with the other cultivars. The main reason for this reduction is mostly attributed to suppression of growth occurring under salinity stress during the early developmental

Table 2. Effect of different levels of salinity on the various yield parameters and harvest index in the kabuli and desi chickpea cultivars.
(Figures in parentheses represent percentage decrease (-) over control)

Soil Salinity ($dS\ m^{-1}$)	FNP*	PNP*	SNP*	SWP*	100 SWP*	TDW*	HI*
			CSG 9651 kabuli				
Control	16.60	16.00	24.00	5.00	20.80	7.58	0.65
4 $dS\ m^{-1}$	16.00	15.60	22.00	4.40	20.00	7.30	0.60
	(3.60)	(2.50)	(8.30)	(12.00)	(3.80)	(3.60)	
6 $dS\ m^{-1}$	15.80	15.20	21.00	4.10	19.50	6.84	0.59
	(4.80)	(5.00)	(12.50)	(18.00)	(6.20)	(9.70)	
8 $dS\ m^{-1}$	15.40	15.00	20.60	3.80	18.40	6.60	0.57
	(7.20)	(6.20)	(14.10)	(24.00)	(11.50)	(12.90)	
			BG 267 kabuli				
Control	12.00	10.00	20.00	2.98	14.90	5.78	0.56
4 $dS\ m^{-1}$	10.40	8.40	17.20	2.44	14.30	4.80	0.50
	(13.30)	(16.00)	(14.00)	(18.10)	(5.30)	(16.90)	
6 $dS\ m^{-1}$	8.80	7.20	15.60	2.18	13.90	4.38	0.49
	(26.60)	(28.00)	(22.00)	(26.00)	(6.70)	(24.20)	
8 $dS\ m^{-1}$	7.80	6.40	14.00	1.80	12.80	3.90	0.46
	(35.00)	(36.00)	(30.00)	(39.50)	(14.00)	(32.50)	
			CSG 8962 desi				
Control	15.60	13.20	22.00	3.60	16.30	6.00	0.60
4 $dS\ m^{-1}$	14.60	12.00	20.00	3.10	15.50	5.76	0.53
	(6.40)	(9.00)	(9.00)	(13.80)	(4.90)	(4.00)	
6 $dS\ m^{-1}$	13.80	11.60	18.20	2.80	15.30	5.30	0.52
	(11.50)	(12.10)	(17.20)	(22.20)	(6.10)	(11.60)	
8 $dS\ m^{-1}$	12.80	10.80	17.30	2.50	14.40	4.92	0.50
	(17.90)	(18.10)	(21.30)	(30.50)	(11.60)	(18.00)	
			DCP 92-3 desi				
Control	10.60	8.40	18.00	2.40	13.30	5.00	0.48
4 $dS\ m^{-1}$	8.00	6.20	14.30	1.80	12.50	3.90	0.46
	(24.50)	(26.10)	(21.10)	(25.00)	(6.90)	(22.00)	
6 $dS\ m^{-1}$	6.40	5.00	10.40	1.28	12.30	3.10	0.41
	(39.60)	(40.40)	(42.20)	(46.00)	(7.50)	(38.00)	
8 $dS\ m^{-1}$	5.00	4.00	7.50	0.84	11.20	2.40	0.35
	(52.80)	(52.30)	(58.30)	(65.00)	(15.70)	(52.00)	
		Mean of 6 replicates					

* FNP = flower number per plant PNP = Pod number per plant SNP = Seed number per plant
SWP = Seed weight per plant TDW = total dry weight per plant HI = Harvest index

LSD (5%)**	A = 0.24	A = 0.90	A = 0.70	A = 0.05	A = 0.15	A = 0.50	A = 0.20
	T = 0.40	T = 0.70	T = 0.60	T = 0.15	T = 0.28	T = 4.15	T = 3.50
	I = 1.32	I = 1.60	I = 1.42	I = 0.50	I = 1.36	I = 6.20	I = 5.60

**A = Age T = Treatment I = Interaction

stages of plants. The various yield attributes and yields were affected by salinity in all chickpea cultivars. The percentage reduction in pod and seed numbers was more drastic which resulted in a significant decline in weight of seeds, 100-seed weight and harvest index of all the cultivars. The decrease in various yield parameters was more severe in desi cultivars compared with kabuli types, which may be in turn related to lower total plant dry mass accumulation in desi cultivars under salinity. Reduction in yield under salinity may be a cumulative effect of various factors like decline in number of flowers, pod setting, the number of ovules fertilised and nurtured into healthy seeds, and thus the number of seeds per pod and seed weight. Among the various yield attributes studied, the number of flowers per plant as well as the seed weight per plant decided the maximum quantum of reduction in the harvest index among the desi and kabuli cultivars under salt stress. The results of decline in crop yield under salinity are consistent with previous findings (Bishnoi et al., 1990; Sharma et al., 1993). Negative effects of salinity on the harvest index seemed to be directly correlated with reduced plant dry mass production in the desi cultivars and hence with an inadequate supply of photosynthates to the developing seeds.

Conclusion

In the light of these results, it is concluded that saline soils inhibit the growth and harvest index of different chickpea cultivars. However, important variability in terms of growth, dry matter accumulation and crop yield was observed amongst different cultivars of chickpea. The better performance of a genotype under saline conditions seems to be determined mainly by the tolerance of the legume host plant. In general, both kabuli cultivars seemed to have a better potential for salt tolerance compared with the desi cultivars. Even the sensitive kabuli exhibited significantly higher salt resistance than the sensitive desi. The existence of intraspecific genetic variability among chickpea cultivars, as shown in this work, might be useful in selecting optimal cultivars to increase agricultural production in soils subject to salinity.

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