

Genotypic differences in seed yield, K : Na ratio and leaf metabolism of cumin (*Cuminum cyminum* L.) under salt stress

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Abstract

Responses of five genotypes (UC-198, UC-220, UC-223, RZ-19 and RZ-209) of cumin (*Cuminum cyminum* L.) irrigated with water having two levels of salinity (0.2 and 10 dSm⁻¹) on shoot dry weight, seed yield, K : Na ratio and leaf metabolism at the flowering stage were studied. Increased salinity significantly reduced seed yield and shoot dry matter in all the genotypes. However, RZ-19 displayed higher salt tolerance than UC-198 and RZ-209 whereas UC-220 and UC-223 showed intermediate tolerance to salinity in terms of seed weight and shoot dry matter. Adverse effects of salinity on the levels of total chlorophyll, soluble protein, free amino acids, starch, reducing sugars and nitrate reductase activity were consistently less in tolerant genotype RZ-19 as compared to sensitive genotypes, UC-198 and RZ-209. Moreover sensitive genotypes had higher concentration of Na and lower concentration of K and consequently lower K : Na ratio under salt stress as compared to the tolerant genotype. These differential genotypic responses have been discussed in the light of the present knowledge.

Key words: *Cuminum cyminum*, genetic variation, salt tolerance

Introduction

Cumin (*Cuminum cyminum* L.) is an important seed spice in India, cultivated in Rajasthan and Gujarat over an area of 0.15 million ha. However, the productivity of the crop is quite low (about 518 kg ha⁻¹) which needs improvement through genetic manipulation and better management practices (Mehta 1989; Singh & Rao 1994). The problem of soil moisture stress and prevalence of poor quality ground water in many arid and semi-arid regions in the states of Rajasthan and Gujarat often restrict the growth of irrigated crops (Dhir 1977; Garg & Lahiri 1986).

Zidan & Elewa (1995) reported that cumin tolerated NaCl salinity upto 200 mM during germination and seedling growth. Garg *et al.* (2002) observed that salinity levels at and above 8 dSm⁻¹ significantly reduced seed yield, nutrient uptake and levels of certain leaf metabolites of cumin. However, scanty information on the association of physiological and biochemical parameters with salt tolerance in crop plants and particularly in cumin is a major impediment for the development of salt tolerant genotypes. Although genotypic differences in ionic composition and metabolic changes in tolerant and sensitive

genotypes of principal arid zone crops have been reported under saline conditions (Garg *et al.* 1990, 1999; Lahiri *et al.* 1996) such information is lacking in cumin. Therefore, the present investigation was conducted to ascertain salinity-induced changes in growth, yield, mineral composition and leaf metabolism of cumin genotypes.

Materials and methods

The present study was conducted with five genotypes (UC-198, UC-220, UC-223, RZ-19 and RZ-209) of cumin under pot culture conditions. Plants were grown in sealed glazed pots containing 40 kg loamy sand soil (7.1% clay, 5.9% silt, 63.1% fine sand and 24.1% coarse sand) having 0.28% organic carbon and 0.023% total nitrogen. The soil contained 80, 15 and 120 kg ha⁻¹ of available N, P and K, respectively. Plants received a basal dose of 30 kg ha⁻¹ N and 20 kg ha⁻¹ P₂O₅. Ten seeds were sown in each pot but only three uniform plants were maintained after emergence in each pot. At 20 days after sowing (DAS) 40 pots under each genotype were divided into two equal sets where first set was irrigated at weekly interval with saline water (10 dSm⁻¹) having the salts in the same proportion (50% NaCl, 15% Na₂SO₄, 10% each of NaHCO₃, MgCl₂ and CaCl₂ and 5% MgSO₄) as commonly found in local ground waters (Dhir 1977). Another set irrigated with tap water (0.20 dS m⁻¹) throughout the growing period served as control. Thus there were 10 treatments with 20 replicates (pots) each. Fresh leaf tissue was analysed, in quadruplicate, at flowering stage (75 DAS) for the concentrations of soluble protein (Lowry *et al.* 1951), free amino acids (Yemm & Cocking 1955), total chlorophyll (Arnon 1949), starch (Yemm & Willis 1954) and reducing sugar (Nelson 1944) as well as for the activity of nitrate reductase (Jaworski 1971) in the same set of leaves (2nd, 3rd and 4th whorl of leaves).

Observations on final shoot dry weight and seed yield based on randomly arranged ten pots under each treatment were also recorded. Potassium and sodium concentrations were analyzed (Jackson 1973), in triplicate,

from representative dry shoot samples at harvest. All the data were analysed by adopting two-way analysis of variance in a completely randomized design.

Results and discussion

Salt stress significantly decreased seed yield and shoot dry matter in all the genotypes (Fig.1). However, reduction in seed yield was maximum in UC-198 (62.7%) followed by RZ-209 (53.0%) whereas RZ-19 recorded the minimum decrease (24.2%) as compared to respective controls. Genotypes UC-220 and UC-223 with 48.7% and 41.2% reduction in seed yield displayed intermediate tolerance to salinity.

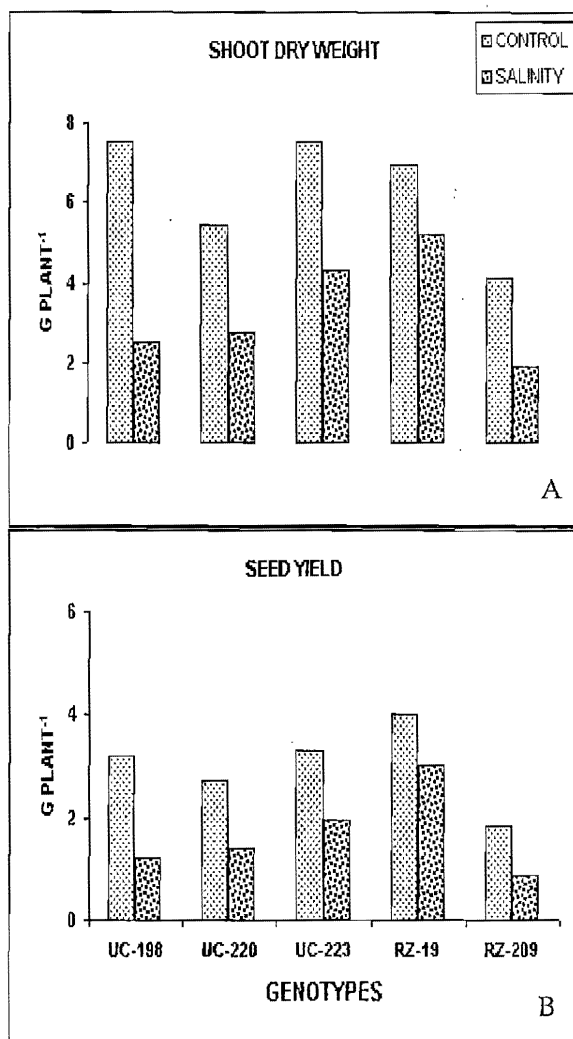


Fig. 1. Effect of salt stress (10 dSm⁻¹) on cumin genotypes: A. Shoot dry weight; B. Seed yield

Genotype RZ-19 produced highest seed yield both under control and saline conditions followed by UC-223. In RZ-209, however, the seed yield was minimum under both control and saline conditions. Data on shoot dry matter also showed similar trend of results where RZ-19, showed the minimum (25.4%) and UC-198 the maximum reduction (66.8%) in dry matter as compared to control plants. Thus data on plant performance indicated that cumin genotypes displayed significant differences when irrigated with saline water (10 dSm⁻¹). Genotypic differences to salt stress have been reported earlier for a number of crops (Lahiri *et al.* 1996; Garg *et al.* 1999; Burman *et al.* 2001). Genotypes UC-198 and RZ-209 which experienced more than 50% reduction in seed yield at 10 dSm⁻¹ have been categorised as sensitive while RZ-19 which registered less than 25% reduction in seed yield has been considered tolerant in the present study. The remaining two genotypes UC-220 and UC-223, where reduction was between 40-50%, have been categorized as moderately sensitive.

The study of diverse metabolic parameters at the flowering stage indicated that increased salinity significantly reduced the concentrations of total chlorophyll and starch but increased reducing sugars (Table 1). The saline water irrigation decreased the chlorophyll content in all the genotypes but in the tolerant genotype RZ-19 the decrease (1.0%) was not significant. This decrease was

maximum (23.4%) in sensitive genotype RZ-209. However, highest decline in starch concentration was in UC-198 (14.8%) followed by RZ-209 (11.1%) while it was least in the tolerant genotype RZ-19. This could be due to the adverse effect of salinity on photosynthesis as reported for other crops (Gale *et al.* 1967). Salinity-induced changes in reducing sugars were also higher in sensitive genotypes, UC-198 and RZ-209 as compared to tolerant genotype RZ-19. Earlier studies have also indicated larger decline in the levels of total chlorophyll and starch due to salinity stress in sensitive than tolerant genotypes of different crops (Varshney 1980; Lahiri *et al.* 1996; Burman *et al.* 2001). Rathert (1983) reported salinity mediated greater accumulation of reducing sugars in a sensitive than tolerant genotypes of cotton. Lahiri *et al.* (1996) made similar observations with sensitive and tolerant genotypes of clusterbean under soil salinity. The changes in the contents of reducing sugars and starch may be due to stress-mediated breakdown of starch. However, alterations in rates of net photosynthesis due to stomatal and non-stomatal factors besides loss of pigmentation are not ruled out.

Increased salinity adversely influenced the nitrogen metabolism of cumin plants as revealed by data on nitrate reductase (NR) activity and levels of soluble protein and free amino acids (Table 2). The decrease in soluble protein with an increase in free amino acids indicated that protein hydrolysis was en-

Table 1. Effects of salt stress (10 dSm⁻¹) on concentrations (mg g⁻¹ fresh weight) of total chlorophyll, starch and reducing sugars of cumin genotypes at the flowering stage

Genotype	Total chlorophyll		Starch			Reducing sugars			
	Control	Salt	Control	Salt		Control	Salt		
UC-198	1.046	0.948(9.4)*	14.96	12.75(14.8)*		2.09	2.88(37.7)**		
UC-220	1.149	1.132(1.5)	18.02	16.48(8.6)		2.50	3.02(20.8)		
UC-223	1.186	1.056(11.0)	18.36	16.53(10.0)		2.72	2.98(9.6)		
RZ-19	1.092	1.082(1.0)	22.50	20.53(8.8)		2.77	2.88(4.0)		
RZ-209	1.267	0.971(23.4)	21.75	19.34(11.1)		2.42	3.14(29.7)		
Mean	1.148	1.038(9.6)	19.12	17.13(10.5)		2.50	2.98(19.2)		
CD at 5%	Genotype	Salinity	GxS	Genotype	Salinity	GxS	Genotype	Salinity	GxS
	0.030	0.019	0.043	0.86	0.55	NS	0.25	0.16	0.35

*per cent decrease over control

** per cent increase over control

hanced by salinity. This dislocation of protein metabolism was further obvious from the reduced activity of nitrate reductase (NR) under salt stress in all the genotypes. Sensitive genotypes RZ-209 and UC-198, however, recorded higher decrease (49.7 to 38.7%) as compared to tolerant RZ-19 (17.1%) and moderately sensitive genotypes UC-220 and UC-223 (22.6 to 27.4%). Likewise, less decline in soluble protein concentration was recorded in RZ-19 (9.3%) and UC-220 and UC-223 (15.7 to 24.9%) whereas sensitive genotypes UC-198 and RZ-209 showed more reduction (30 to 35%) as compared to respective controls. Maintenance of higher NR activity as well as high protein concentration under salt stress in tolerant as compared to sensitive genotypes is in concurrence with the earlier reports in pearl millet (Sharma & Gill 1992), mustard (Garg *et al.* 1999) and clusterbean (Lahiri *et al.* 1996). It was further observed that salinity increased the levels of free amino acids in all the genotypes but tolerant genotype RZ-19 accumulated less free amino acids (6.0%) than sensitive genotypes RZ-209 (34.2%) and UC-198 (23.8%). Thus derangements in nitrogen metabolism were far greater in sensitive than tolerant genotypes of cumin. Such a differential behaviour of genotypes under salinity has been reported in other crops too (Garg *et al.* 1990, 1999).

The concentration of potassium in the shoots

at harvest was reduced significantly under the influence of salt stress in all the genotypes but there was a sharp increase in the concentration of sodium (Fig. 2). Reduction in K concentration varied between 24.5 to 30.8% with minimum in RZ-19 and maximum in UC-223. However, increase in Na concentration was very high and varied from 75% in RZ-19 to 225% in RZ-209 over respective controls. In a number of earlier studies on genotypes sensitive to salt stress in different crops like soybean (Abel & Mackenzie 1964), wheat (Rush & Epstein 1976; Garg *et al.* 1990), Indian mustard (Garg *et al.* 1999) and clusterbean (Lahiri *et al.* 1996) high concentrations of Na and low concentration of K are reported. A similar trend was observed in cumin genotypes in the present study.

As a consequence of decreased K and increased Na concentrations under salt stress, the K:Na ratio also decreased considerably in all the genotypes and the genotype RZ-19 maintained wider K:Na ratio under saline conditions (Fig. 2). On the contrary sensitive genotypes RZ-209 and UC-198 displayed lower K:Na ratio. Maintenance of wider K:Na ratio has generally been associated with higher salt tolerance (Greenway & Munns 1980; Garg *et al.* 1999). It has also been reported that protein synthesis in wheat germplasm is less adversely affected due to salinity when K:Na ratio is wider (Greenway & Munns 1980). The present study lends sup-

Table 2. Effect of salt stress (10 dS m⁻¹) on nitrate reductase activity and concentrations of soluble protein and free amino acids of cumin genotypes at flowering stage

Genotype	Nitrate reductase (μ mol NO ₂ g ⁻¹ fw h ⁻¹)			Soluble protein (mg g ⁻¹ fw)			Free aminoacids (mg g ⁻¹ fw)		
	Control	Salt		Control	Salt		Control	Salt	
UC-198	5.73	3.51(38.7)*		9.79	6.42(34.9)*		1.30	1.61(23.8)**	
UC-220	5.49	4.25(22.6)		11.21	9.45(15.7)		1.53	1.70(11.1)	
UC-223	5.73	4.16(27.4)		10.86	8.16(24.9)		1.59	1.83(15.1)	
RZ-19	6.37	5.28(17.1)		12.40	11.25(9.3)		1.49	1.58(6.0)	
RZ-209	6.16	3.10(49.7)		13.44	9.41(30.0)		1.49	2.00(34.2)	
Mean	5.90	4.06(31.2)		11.54	8.94(22.5)		1.48	1.74(17.6)	
CD at 5%	Genotype	Salinity	GxS	Genotype	Salinity	GxS	Genotype	Salinity	GxS
	0.38	0.25	0.55	0.81	0.51	1.14	0.13	0.08	0.18

*per cent decrease over control

** per cent increase over control

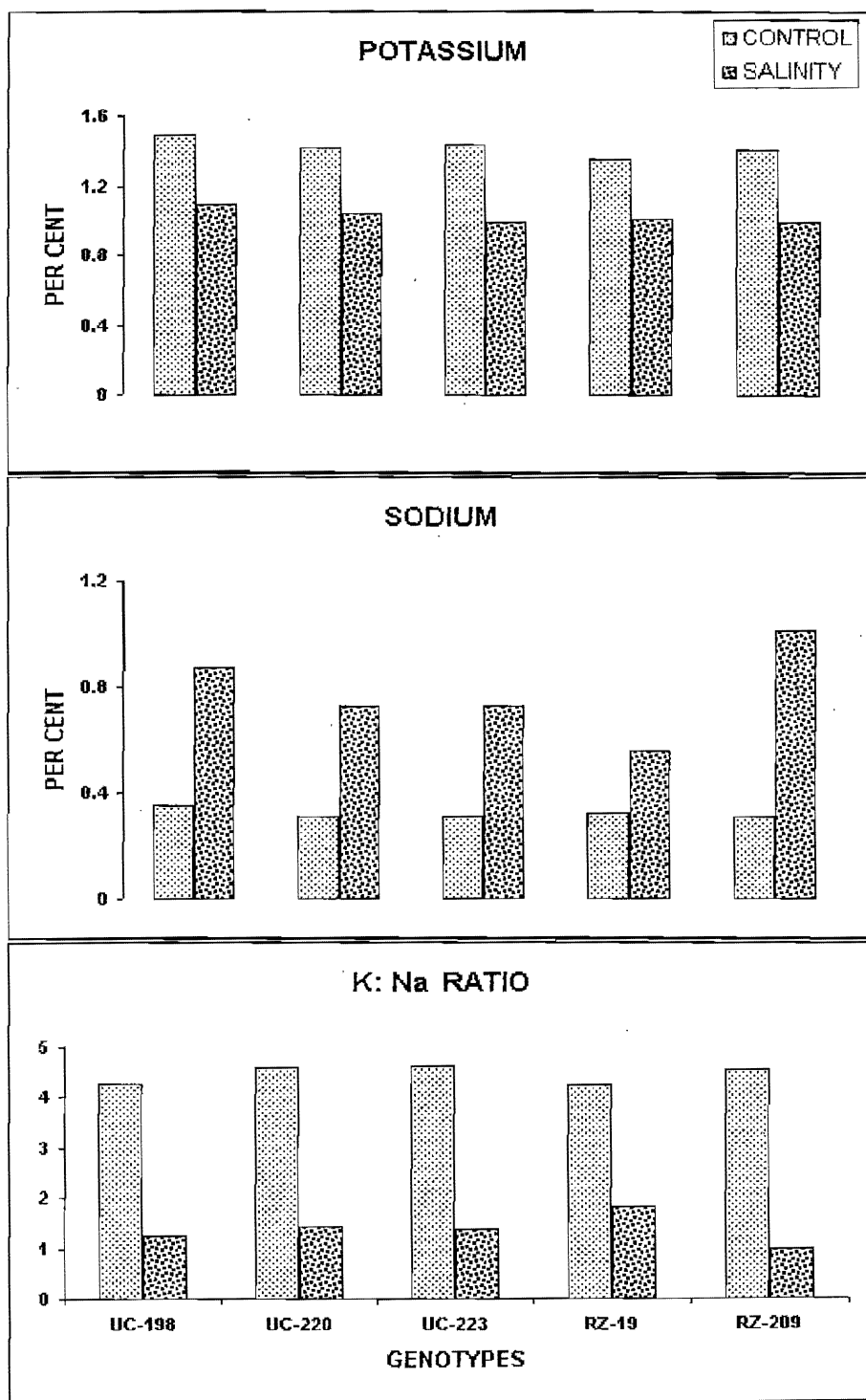


Fig. 2. Effect of salt stress (10 dSm⁻¹) on concentrations of K, Na and K: Na ratio in shoots of cumin genotypes

port to this contention.

Evidences presented here indicate the detrimental effects of salinity on growth, seed yield, K and Na concentrations and leaf metabolism in diverse cumin genotypes. However, genotype RZ-19 displayed better salt tolerance as compared to RZ-209 and UC-198 while UC-220 and UC-223 displayed an intermediate salt tolerance. In general sensitive genotypes (UC-198 and RZ-209) experienced more adverse metabolic alterations than tolerant genotype (RZ-19) due to higher uptake of Na and less favourable K: Na ratios.

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