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DIFFERENTIAL RESPONSE OF CULTIVATED COTTON SPECIES (*GOSSYPIUM* SPECIES) TO SALINITY

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ABSTRACT

Cultivated cotton species are known to differ widely for their salinity tolerance. Asiatic or diploid *(G. arboretum* & *G. herbaceum)* cotton is more tolerant than upland or tetraploid (*G. hirsutum* & *G. barbadense)* cotton. In pot culture experiments with increasing salinity levels, it was observed that the Na accumulated in different parts causing salt injury to *G. hirsutum,* while *G. arboreum* excluded Na and showed salinity tolerance. Na had a detrimental effect on leaf expansion of *G. hirsutum.* On the contrary, *G. arboreum* and *G. herbaceum* had relatively higher leaf expansion under salinity, which enabled them to produce higher yield in comparison to *G. hirsutum.*

INTRODUCTION

Amongst field grown crops, cotton is classified as moderately salt-tolerant. Cotton can withstand salinity to an extent of 7-8 dS m^{-1} without much reduction in yield (Mass & Hoffman, 1977). Wide variability was reported for salinity tolerance across the cultivated species (Hebbara et al., 1996). There are four cultivated cotton species namely the diploids *G. arboreum* and *G. herbaceum* and the tetraploids, *G. hirsutum* and *G. barbadense*. In India all four of these are grown. The diploid ones are known to be tolerant to drought and salinity as they are acclimatized to coastal (Liu et al., 1993) as well as desert ecosystem (Stewart, 1995).

The mechanism of salinity tolerance is complex because the effect of salt involves osmotic stress, ion toxicity and mineral deficiencies (Hasegawa et al., 2000; Munns, 1993; 2002). Osmotic stress (Munns 1993, 2002) and water stress (Pardossi et al. 1998) are effective in the beginning (hours to few days) of exposure to salt, and ion toxicity becomes important in affecting plant growth after prolonged exposure. Water stress contributes to inhibition of yield (Fowler, 1986), stomatal conductance, P_N and transpiration (Gossett et al., 1991). Some glycophytes tolerate high external salinity by way of accumulating Na and Cl (Binzel et al., 1988). However, most of the glycophytes respond by the exclusion of Na or retention in root and stem, so that minimum amount is accumulated in leaves. Even in leaves sodium is sequestered in vacuoles. To counter the osmotic effect of Na some plants accumulate proline as an osmoprotectant (Yoshiba et al.,1997), while others are known to have

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higher activity of antioxidant enzymes catalase and peroxidase (Gossett et al., 1991).

In the present study the salinity tolerance mechanism of *G. hirustum* and diploid cottons *G. arboreum* and *G. herbaceum* were compared under increasing salinity stress conditions.

MATERIALS AND METHODS

A pot culture experiment was conducted in the greenhouse at Central Institute for Cotton Research, Nagpur. Popular cultivated varieties of G. *hirsutum* (LRA 5166 & LRK 516), *G. arboreum* (G 27 & AKA 8401) and *G. herbaceum* (Jayadhar & DB-3-12) were grown in earthen pots (capacity16 kg dry soil). One day before the sowing, the pots were saturated with 0, 5, 10, 15 & 20 dS m^{-1} NaCl solutions. Upon germination, plants were irrigated with saline water every alternate day. All the pots received equal quantity of water. After 20 days of germination, a single plant was retained in each pot. At flowering stage photosynthesis, leaf area, leaf water potential and the enzyme activity were measured.

The P_N of the youngest fully expanded leaf (3^{rd} leaf from top) was measured with a Portable Photosynthesis System (model CIRAS-1, PP systems, UK). Measurements were taken twice under conditions of full sunlight, between 1200 and 1500 µmole m^{-2} s^{-1}. Same leaf was excised and used for the measurement of leaf water potential with Scholander Pressure Chamber apparatus. Leaf area was measured with a leaf area meter (LICOR-3000). Proline, catalase and peroxidase contents were determined in the topmost fully opened third leaf of control and 15 dS m^{-1} salinity treated plants (Sadasivam & Manickam, 1996). Catalase activity was measured by following the consumption of H_2O_2 at 240 nm. The rate of Guaiacol oxidation was measured spectrophotometrically at 436 nm to assay the peroxidase activity.

At harvest, the plants were uprooted and the roots were washed in deionised water to remove the soil. Plant parts were separated into root, shoot, leaf and fruiting parts and their dry weights were recorded after drying the sample at 75°C for 72 h. Potassium and sodium concentrations of root, stem, leaf and

Table 1. Seed cotton yield of varieties belonging to *G. hirsutum*, *G.arboreum* and *G. herbaceum* grown in soil with increasing concentrations of NaCl.

Species	Varieties	Salinity level (dS m^{-1})					
		0	5	10	15	20	Mean
G. hirsutum	LRA 5166	13.125	12.47	7.52	5.675	2.44	8.25
	LRK 516	13.45	14.33	7.62	6.45	3.51	9.07
G. arboreum	G 27	10.58	8.98	7.48	7.85	4.72	7.92
	AKA 8401	10.35	9.72	8.67	7.20	3.66	7.92
G. herbaceum	JAYADHAR	10.29	9.17	7.58	7.36	5.64	8.00
	DB-3-12	10.59	8.97	7.21	8.16	5.85	8.15
	Mean	11.40	10.61	7.68	7.11	4.30	
	CD at 5%						
	Var	NS					
	Sal	1.29					
	V X S	3.17					

fruiting parts of *G. hirsutum* and *G. arboreum* were analyzed using flame photometer.

Analysis of variance (ANOVA) was performed by MSTAT statistical package and treatment means compared using the least significant difference (LSD) test at 5% level.

RESULTS

From Table 1 it is clear that *G. hirsutum* varieties had higher yield as compared to G. *arboreum* and G. *herbaceum* varieties at 0

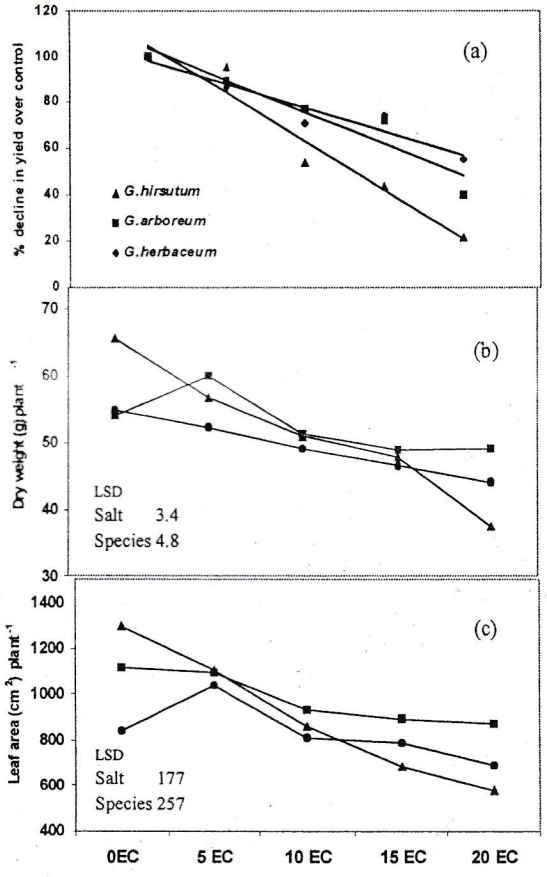

Fig.1. Per cent decline in seed cotton yield over control (a), plant dry weight (b) and leaf area per plant (c) of three cotton species grown in soil with increasing concentration of NaCl. Each value is mean of varieties (LSD values at $p< 0.05$).

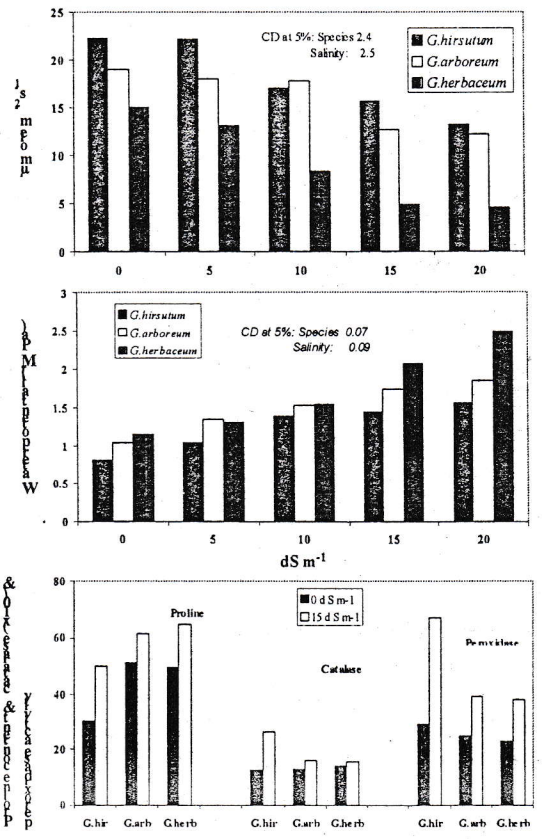

Fig. 2. Photosynthesis (a) and leaf water potential (b) at different salinity levels and proline content, catalase and peroxidase activity of control and 15 dS m^{-1} salinity treated plants of *G. hirsutum*, *G. arboreum* and *G. herbaceum*. Each value is mean of varieties (LSD values at $p< 0.05$).

dS m^{-1}. Yield did not change significantly at 5 dS m^{-1}. However, at 10 dS m^{-1} and beyond, yield reduced significantly in all the varieties irrespective of the species. *Hirsutum* was more sensitive than *arboreum* and *herbaceum*. At 20 dS m^{-1}, yield of all these three declined by 78, 60 and 45%, respectively (Fig. 1a). Similar trend was seen for biomass production and leaf area expansion of all the species (Fig. 1b, c). At 20 dS m^{-1}, plant dry weight (Fig. 1b) and leaf

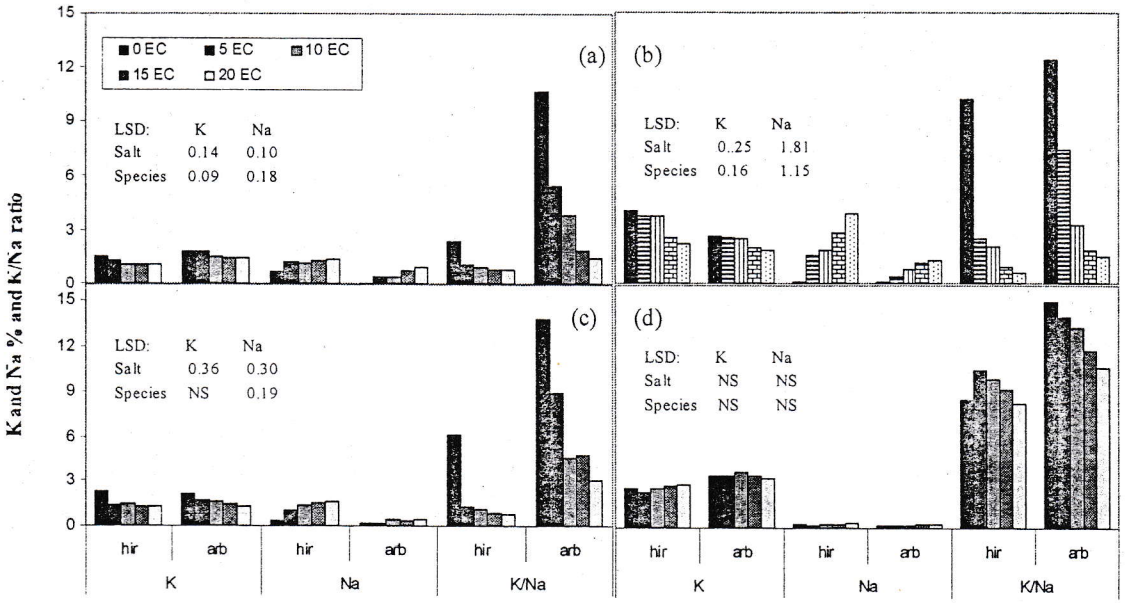

Fig. 3. K and Na per cent and K/Na ratio of root (a), leaf (b), stem (c) and fruiting parts (d) of *G. hirsutum* and *G. arboreum* grown in soils with increasing concentrations of NaCl. Each value is mean of varieties (LSD values at $p< 0.05$).

area (Fig. 1c) decreased by 43, 20 and 19% and 55, 22 and 18% in *hirsutum*, *arboreum* and *herbaceum*, respectively.

Both under saline and non-saline conditions, G. *hirsutum* had significantly higher P_N as compared to G. *arboreum* and *G. herbaceum*, it being lowest in *G. herbaceum.* Salinity at 10 dS m^{-1} and above, significantly reduced P_N in all the species except *arboreum* in which significant decline was seen at 15 dS m^{-1} and above (Fig. 2). At 20 dS m^{-1}, P_N declined by 35% in *hirsutum* as against 40 and 70% in *arboreum* and *herbaceum,* respectively. Similar to P_N, the leaf water potential was the highest in *G. hirsutum* and lowest in *G. herbaceum* both under saline and non saline conditions (Fig. 2).

Contrary to P_N and leaf water potential, leaf proline content was low in the control and salt treated *hirsutum* as compared to *arboreum* and *herbaceum*. Under salinity, proline accumulation was the highest in *G. hirsutum* (62%) followed by *G. arboreum* (29%) and *G. herbaceum* (30%) (Fig. 2). Similarly, the antioxidant enzymes catalase and peroxidase activity increased under salinity (Fig. 2). At 15 dS m^{-1}, catalase and peroxidase activity was almost doubled in *hirsutum,* while the increase was only marginal in *arboreum* and *herbaceum*.

In Fig. 3, K and Na concentrations of different plant parts are presented. Amongst the different plant parts, fruiting parts had high K content followed by leaf, stem and roots. As the salinity level increased, the K^+ content of root (Fig. 3a), stem (Fig. 3c) and leaf (Fig. 3b) decreased significantly, but in the fruiting parts it remained at par with the control plants (Fig. 3d). On the contrary, Na^+ content of root, stem and leaf increased significantly with increasing levels of salinity except fruiting parts, where it was similar to control plants.

Na content was highest in leaves followed by root, stem and fruiting part. *Hirsutum* accumulated significantly higher Na^+ in different plant parts as compared to *arboreum*. As a consequence, the K/Na ratio was low in *G. hirsutum*, while *G. arboreum* had significantly higher ratio in control and at all salinity levels. In both the species this ratio fell sharply under salinity in all the plant parts except the fruiting parts.

DISCUSSION

Salinity treatment decreased the growth and yield of cotton at and above 10 dS m^{-1}, whereas at 5 dS m^{-1} growth was at par with the control plants, which is in confirmity with the earlier findings (Mass & Hoffman, 1977). Amongst the cultivated species of cotton, G. *hirsutum* was the most sensitive to salinity as indicated by the sharp decline in seed cotton yield and biomass compared to *G. arboreum* and *G. herbaceum*. Earlier workers too observed similar response of cotton species to salinity (Hebbara et al., 1996; Hebbar et al., 2005).

Amongst the notable changes observed with salinity, *G. hirsutum* accumulated Na, while *G. arboreum* excluded it. The Na accumulation in *G. hirsutum* was at the cost of K content of different plant parts. To certain extent, Na can substitute K to maintain the osmotic potential (Hebbar et al., 2000). However, at higher concentrations it caused cell injury (Munns, 1993). Nonetheless, *G. hirsutum* could counter the osmotic effect of Na through the accumulation of proline, which enabled it to have relatively higher leaf water potential and Pn than the other two species under salinity. Further, *G. hirsutum* also had higher antioxidant enzyme activity under salinity whose increased production has been implicated in the protection of photosynthetic machinery (Gossett et al., 1991). Though, plants had devised a mechanism to protect the Pn, but accumulated Na had a deleterious effect on leaf area expansion. Leaf area expansion is known to be more sensitive to salinity than photosynthesis (Munns 1993), which affected the biomass production to a great extent (Brugnoli & Bjorkman, 1992) in *G. hirsutum*.

On the other hand *G. arboreum* excluded Na to a great extent, which is an important mechanism for tolerance under salinity (Janardan et al., 1976). The small amount of accumulated Na reduced the osmotic potential and thus the photosynthesis, but it was not detrimental to leaf area expansion. The sustenance of larger leaf area enabled *G. arboreum* and *G. herbaceum* to produce relatively higher biomass and yield under salinity.

Thus, from the study it is clear that cultivated species of cotton showed differential response to salinity. *G. hirsutum* accumulated more of Na, while *G. arboreum* excluded it. Though, Na injury on Pn could be salvaged through the accumulation of proline and antioxidant enzymes, however it significantly reduced the leaf area expansion of *G. hirsutum*. The sustenance of larger leaf area, on *the other hand enabled G. arboreum and* G. *herbaceum* to produce relatively higher biomass and yield under salinity.

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