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HETEROTIC RESPONSE OF F_1 SORGHUM HYBRIDS TO NaCl SALINITY AT EARLY STAGE OF PLANT GROWTH

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The analysis of variance revealed highly significant differences among 12 genotypes (6 parents and 6 F_1 hybrids) of sorghum, four NaCl solutions and interaction components. The heterotic response of the six hybrids was studied in 100 mM and 150 mM NaCl solution. In 100 mM NaCl, all the hybrids manifested positive and significant amount of heterosis over mid-parent, and when compared with their better parents four hybrids displayed significant increase in root length. Under 150 mM salinity level root length of all the genotypes was inhibited severely; only two hybrids i.e. B-378 Red Lan x QL 10 and INRA 209 X B-378 Red Lan yielded best heterosis and heterobeltosis. The results suggested that manifestation of non-significant and significant heterosis over mid parent is due to the genes acting additively and non-additivelly, respectively, whilst the occurrence of heterobeltosis is by the genes with overdominance.

Key words: Sorghum Hybrids, Heterosis, Salinity.

Introduction

There are many environmental stress factors which affect crop production in the field. The effect of salinity stress on growth and development of plants is probably more severe as compared to others (Shannon 1981). The problem of salinity is wide spread in arid and semi-arid regions and soil generally becomes unsuitable for crop husbandry. Although the engineering approach has proved to be successful in reclaiming the salty deserts, due to escalating cost of labour and energy, the continued running of reclamation projects does not appear economically feasible for developing countries. In these situations plant breeders and geneticists are seeking to modify the plant to suit adverse soil conditions while maintaining reasonable and reliable yields. This biological approach has recently been increasingly emphasized as a possible alternative to utilize saline areas for cultivation (Epstein 1980; Shannon 1984). In the same context the development of salt tolerance in rice (Akbar and Yabono 1975), tomato (Rush and Epstein 1981) and in other crops represents the elegant work of researchers on salt tolerance.

Sorghum currently ranks fourth among the world cereal crops and is a staple food in the semi-arid tropics (House 1987). Therefore, the development of salinity tolerant sorghum genotypes would clearly be of great value. The study of literature showed that sorghum hybrids performed better under optimum and suboptimum growing conditions (Blum 1977). Keeping in view such potential of the hybrids, the present work was carried out to assess the plant material of sorghum in F_1 generation under salt stress conditions in growth chambers.

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Materials and Methods

The plant material used in these studies was developed by crossing six accessions of *Sorghum bicolor* L., namely B-378 Red-Lan, QL-10, Double TX, INRA 133, INRA 209 and INRA 353. The six accessions differed in their salt tolerance (Azhar and McNeilly 1987). Biparental crosses affected were; B-378 Red Lan x QL-10, Double TX x INRA 353, INRA 133 x INRA 209, INRA 209 x B-378 Red Lan, INRA 353 x INRA 133, INRA 353 x INRA 209. The response of six hybrids was assessed using the solution culture technique as used previously by Azhar and McNeilly (1987,1988). The experiment involved four NaCl concentrations i.e. 50, 100, 150 and 200 mM in 1/10 Rorison's nutrient solution. Approximately 12 seeds of each F_1 hybrid and the parents were sown on three layer deep raft of black alkathene beads floating on the surface of 300 cm^3 solution in plastic beakers. The pots were arranged according to completely randomized design with two replicates in a growth chamber maintained at 25 ± 1°C and relative humidity of 80%. Pots were enclosed within perplex chambers to maintain humidity, minimize evaporation of the solutions in the pots and thus rendered changing of solutions unnecessary during the 14 days period of growth.

After two weeks growth the longest root lengths of the random seedlings from each of the two replications were measured in six hybrids and the parents. The mean values of root length of 12 entries were obtained to study their heterotic response to NaCl salinity. Heterosis, indicating percent increase of F_1 over mid parent (MP) and heterobeltosis revealing the superiority of F_1 over better parent (BP) were computed for each of the hybrids only in 100 mM and 150 mM NaCl concentrations, using the formulae of Laosuwan and Atkins (1977).

For testing the significance of heterosis and heterobeltosis, separate analysis of variance of two tests (F_1 + MP) and (F_1 + BP) in the two saline solutions was carried out and the L.S. D. test was performed.

Results and Discussions

The mean data on root length obtained in four NaCl concentrations were subjected to analysis of variance in order to determine whether the differences among the 12 genotypes and four salinity levels were significant (Table 1). The results showed that six hybrids and parents were significantly different from each other ($P \leq 0.01$) in the root length. Four NaCl solutions were also statistically different ($P \leq 0.01$) and highly significant component of interaction between genotypes and NaCl solutions indicated that response of 12 genotypes was markedly different to salinity in the nutrient medium.

The amount of heterosis and heterobeltosis in six hybrids tested in 100 mM and 150 mM NaCl concentrations was computed (Table 2). The positive and highly significant ($P \leq 0.01$) heterotic effect of six hybrids in 100 mM NaCl level appeared to be quite impressive. The extent of heterosis varied from one cross to another and ranged from 26.65 to 89.42 percent. The crosses INRA 133 x INRA 209, INRA 209 x B-378 Red Lan manifested the highest amount of heterosis i.e. 89.42% and 73.30% respectively, followed by B-378 Red Lan x QL-10 and INRA 353 x INRA 209 which showed moderate heterotic effect under 100 mM salinity. The remaining two crosses, Double TX x INRA 353 and INRA 353 x INRA 133, although revealed comparatively low heterotic values i.e., 26.65% and 35.41% respectively, the estimates were statistically highly significant ($P \leq 0.01$). The amount of heterobeltosis in the four combinations was again strikingly different, the lowest values 25.22% and 30.93% were obtained by hybrid B-378 Red Lan x QL-10 and INRA 353 x INRA 209, respectively, and the highest 66.95% and 62.29% by INRA 133 x INRA 209 and INRA 209 x B-378 Red Lan. In other two crosses, the increase of F_1 over better parents, though positive, was non-significant in values ($P \leq 0.05$).

Under increased concentration of 150 mM NaCl, the growth of the parents and the hybrids was inhibited severely. The two crosses B-378 Red Lan x QL-10 and INRA 209 x B-378 Red Lan manifested a highly significant ($P \leq 0.01$) amount of heterosis over their better parents, the magnitude being 112.28% and 77.87%, respectively. The same two crosses also maintained their superiority over the better parents and yielded 98.36% and 61.94%, respectively more heterosis than their better parents.

For the identification of potential genotypes, manifestation of vigorous growth of plant material under saline subtrate is one criterion (Epstein 1983).

The response of six hybrids to NaCl salinity was shown to be markedly different from each other. The greater amount of hybrid vigor is usually manifested when the material tested is geographically diverse and genetically unrelated as suggested by Moll *et al* (1962) and Niehaus and Pickett (1966). Then clear expression of heterotic response in the six hybrids suggested the existence of genetic variability for salt tolerance present in the parents. The greater amount of heterotic effect in the crosses B-378 Red Lan x QL-10, INRA 133 x INRA 209, INRA 209 x B378 Red Lan and INRA 353 x INRA 209 is thus an indication of a greater amount of variation in the parents for salinity tolerance. On the other hand, less genetic diversity contained in the parents of the

Table 1

Analysis of variance of six hybrids and their parents tested under four NaCl solutions

Source of variation	Degree of freedom	Sum of squares	Mean squares	Variance ratio	Probability
Genotypes (G)	11	59.38	5.40	33.01	≤ 0.01
NaCl solution (Sol)	3	4101.28	1367.09	8359.65	≤ 0.01
G x Sol	33	143.44	4.34	26.58	≤ 0.01
Residual effects	48	7.85	0.16		

Table 2

Heterosis in six F_1 hybrids of *Sorghum bicolor* L. for salt tolerance

Hybrids & Parents	100 mM NaCl			Percent increase over		150 mM NaCl			Percent increase over	
	F_1	F_1-MP	F_1-BP	MP	BP	F_1	F_1-MP	F_1-BP	MP	BP
B-378 Red Lan x QL 10	4.32	1.56	0.87	56.52**	25.22**	2.42	1.28	1.20	112.28**	98.36**
Double TX x INRA 353	4.80	1.01	0.55	26.65**	12.94^{NS}	2.03	0.18	0.10	9.73^{NS}	5.18^{NS}
INRA 133 x INRA 209	3.94	1.86	1.58	89.42**	66.95**	1.80	0.44	0.42	32.35^{NS}	30.43^{NS}
INRA 209 x B 378 Red Lan	3.83	1.62	1.47	73.30**	62.29**	2.17	0.95	0.83	77.87^{NS}	61.94**
INRA 353 x INRA 133	3.48	0.91	0.15	35.41**	4.50 NS	1.90	0.35	0.14	22.58^{NS}	7.95^{NS}
INRA 353 x INRA 209	4.36	1.51	1.03	52.98**	30.93**	1.96	0.39	0.20	24.84^{NS}	11.36^{NS}
B 378 Red Lan	2.06	-	-	-	-	1.05	-	-	-	-
Double TX	4.25	-	-	-	-	1.93	-	-	-	-
QL 10	3.45	-	-	-	-	1.22	-	-	-	-
INRA 133	1.80	-	-	-	-	1.34	-	-	-	-
INRA 209	2.36	-	-	-	-	1.38	-	-	-	-
INRA 353	3.33	-	-	-	-	1.76	-	-	-	-
LSD 0.05		0.48	0.56	-	-	-	0.49	0.54	-	-
LSD 0.01		0.67	0.79	-	-	-	0.69	0.76	-	-

MP = Mid-parent; BP = better parent; ** = differences highly significant; NS = differences non-significant.

remaining crosses is evident from their decreased response to the effect of salinity.

The root length is a reliable indicator of high salinity tolerance and is a useful criterion for the identification of plants showing enhanced salt tolerance. Therefore, it would seem to be more advantageous to improve roots of a plant through some means, possibly by heterosis. Previous studies provide evidence that heterosis does occur for root length under non-stress and stress conditions (Blum *et al* 1977; Ekanayake *et al* 1985) and confirmed the results of the present study on salt tolerance in sorghum. Thus the data given here suggest the possibility of selection for longer roots to improve salt tolerance in the species.

It is suggested that significant and positive amount of heterosis in root length is due to genes showing dominance effects in positive direction; non-significant mid-parent heterosis by additive genetic effects and manifestation of significant heterobeltosis is due to positive genes showing overdominance (Paul *et al* 1987). Therefore, the present study reveals that the inheritance of salt tolerance varies from one cross to another and dominance is influenced by alleles with positive and negative genes. Different nature of the genetic system affecting salt tolerance in individual crosses determines the selection and breeding procedures to be followed in handling the subsequent generations.Thus in the populations originating from crosses showing additive effects, selection of individual plants combining favourable additive genes can be successfully made in the early segregating progenies and these genes may be fixed following the pedigree method. However, since the salinity tolerance in the crosses is controlled by non-additive genes, the selection may be delayed till the genes become established in the population. Selected salt tolerant lines may then be included in a breeding programme using genetic male-sterile lines to allow better recombinations of the genes and recurrent selection method would successfully lead to improve salt tolerance in sorghum in such crosses.

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