Association Studies for Salinity Tolerance in Sorghum [*Sorghum bicolor* (L.) Moench]

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A laboratory experiment was conducted to determine the effect of salinity stress (0 dSm-^{1}, dSm-^{1}, 6 dSm-^{1} and 9 dSm-^{1}) on germination and seedling growth of 100 germplasm lines of sorghum (*Sorghum biocolor*), collected from different agroclimate zones of Rajasthan. The analysis of variance for all the traits revealed considerable variability in the experimental material and environments. In present study, the trend of genotypic and phenotypic correlation was similar between different characters. Three genotypes, *viz*., Raj 27, Raj 30 and Raj 4 could be identified for salinity tolerance as they were stable and having bi>I and high germination percentage at the highest (9 dSm-^{1}) salinity level. Another genotype Raj 42 though was not stable but it exhibited higher mean performance in all salinity levels for fresh weight of root per seedlings, coleoptile length, germination percentage and ratio of fresh weight of shoots to roots.

Key Words: Germplasm, Sorghum, Salinity, Variability

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench] is an important cereal crop of the country primarily grown for food, feed, forage and industrial raw material. Soil salinity, in arid and semiarid regions of the world, is a major detrimental factor for crop production. In India, nearly 10 million area is salt affected, out of which 17, 8716 ha area is in Rajasthan (Govt. of India, 2002-03). Plant resistance in context of salinity is not a simple reaction but it is a complex interaction between the plant and operating due to the extent and the constant increase in salt affected areas. Sorghum has been considered relatively more salt tolerant than maize and has potential as a grain and fodder crop for salt affected areas, and also has shown to contain variability for salinity. Breeding of salt tolerant crop varieties for such soils, as proposed by Epstein (1972) is an attractive possibility in combination with appropriate management programme. The development of high yielding salinity tolerant sorghum varieties is the best option to increase the productivity in saline soils. So the present investigation was undertaken to study the variability in germination and seedling traits at various levels of salinity and to identify sorghum genotypes for tolerance to salinity at germination and seedling stage.

Materials and Methods

Seeds of 100 germplasm of sorghum (*Sorghum bicolor*), collected from different agroclimatic zones of Rajasthan were evaluated in four salinity levels (0 dSm-^{1}, 3 dSm-^{1}, 6 dSm-^{1} and 9 dSm-^{1}). Four types of test solution having salinity levels 0, 3, 6, 9 dSm-1 were prepared artificially by the addition of requisite amount of NaCl, $CaCl_2$, $MgSo_4$ & $NaHCO_3$ to Hoagland solution and used for watering the test crops as per need arise. Twenty seeds of each germplasm were surface sterilized with 0.1% $HgCl_2$ solution for 5 minutes followed by at least three washings with distilled water and placed in autoclaved petridishes. The whole experiment was replicated three times. The petridishes were watered with 5 ml of sterile test solution after draining out the previous day's solution, during the first five days. After 5th day each petridish was watered with 10 ml of the test solution. All the petridishes were kept in dark for 72 hours, later the dishes were exposed to artificial light (10 hrs/day) achieved by the use of fluorescent lamps and incandescent bulb. On the 11th day, observations were recorded for various germination and early seedling growth traits, *viz*., germination percentage, seedling height, coleoptile length, fresh weight of shoot per seedling, fresh weight of root per seedling, dry weight of shoot per seedling, dry weight of root per seedling, ratio of fresh weight of shoots to roots and ratio of dry weight of shoots to roots. Data on different characters were subjected to the appropriate statistical analysis.

Results and Discussion

Mean sum of squares due to genotype was significant for all the characters at all the salinity levels (Table 1). Similarly, difference among salinity levels and interaction of genotypes with environments were also significant for all the characters. In fact, variation in whole plant biomass responses to salinity was considered to provide the best means of selection (Krishnamurthy *et al.*, 2007). Variation

for germination percentage and seedling characteristics at different salinity level were widely reported (Khalvati *et al.*, 2001; Khan *et al.*, 2003). The salinity gradient adversely affected the mean value of all the characters. The *per se* performance decreased with increasing the salinity. Such effects were also noticed by (Mcharia *et al.*, 1995; Kumari and Pillai, 1997). Comparison of mean performance of genotype in different salinity levels revealed that genotype Raj 42 exhibited higher values for various traits, *viz.*, germination percentage, coleoptile length and fresh weight of shoot per seedling.

In the present investigation, the magnitude of phenotypic coefficient of variation (PCV) was higher than Genotypic coefficient of variation (GCV) in all the four salinity levels for all the characters, however, magnitude of both moved together (Table 2). In the present study, high GCV was observed for dry weight of root per seedling and ratio of dry weight of shoots to dry weight of roots in all the four salinity levels. Besides these traits, some characters had high GCV in specific environment like dry weight of shoot per seedling in S_0 ad S_1 and ratio of fresh weight of shoots to fresh weight of roots in S_3. Similar type of results of high GCV for one or the other aforesaid character were reported by Mehdi and Ahsan (2002).

In present study, heritability was high for fresh weight of root per seedling, dry weight of root per seedling, fresh weight of shoot per seedling and ratio of fresh weight of shoots to fresh weight of roots in all the four salinity levels. It indicated that heritability of these characters was less

Table 1. Mean squares for different characters in different salinity levels in sorghum

S.No.	Characters	Salinity levels	Genotype [99]	Error [200]
1	Germination Percentage	S_0	232.15**	5.33
		S_1	248.98**	5.00
		S_2	252.29**	5.42
		S_3	376.27**	5.92
2	Seedling height (cm)	S_0	24.42**	0.06
		S_1	14.63**	0.32
		S_2	14.66**	0.01
		S_3	23.44**	0.02
3	Coleoptile length (cm)	S_0	4.08**	
		S_1	3.60**	0.02
		S_2	4.68**	0.04
		S_3	11.48**	0.02
4	Fresh weight of shoot per seedling (g)	S_0	0.27**	6.433e-05
		S_1	0.23**	3.633e-05
		S_2	0.22**	4.934e-05
		S_3	0.21**	4.234e-05
5	Fresh weight of root per seedling (g)	S_0	0.03**	3.45e-07
		S_1	0.03**	4.15e-07
		S_2	0.03**	2.5e-08
		S_3	0.03**	6.5e-08
6	Dry weight of shoot per seedling (g)	S_0	0.03**	1.633e-05
		S_1	0.05**	6.5e-08
		S_2	0.02**	6.5e-08
		S_3	0.01**	6.5e-08
7.	Dry weight of root per seedling (g)	S_0	0.01**	6.5e-08
		S_1	0.02**	2.65e-07
		S_2	0.01**	4.15e-07
		S_3	0.01**	5.2e-07
8	Ratio of fresh weight of shoot to fresh Weight of root	S_0	62.69**	0.001
		S_1	66.24**	0.002
		S_2	44.54**	0.001
		S_3	64.78**	0.001
9	Ratio of dry weight of shoot to dry Weight of root	S_0	37.91**	0.01
		S_1	77.32**	0.48
		S_2	29.86**	0.02
		S_3	32.72**	0.26

Table 2. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (H) and genetic gain (GG) for different characters in sorghum

S.No.	Characters	Salinity Level	GCV	PCV	H2	GG
1	Germination percentage	S_0	10.87	11.25	93.35	21.63
		S_1	11.86	12.23	94.15	23.72
		S_2	12.84	13.27	93.76	25.62
		S_3	18.06	18.49	95.38	36.33
2	Seedling height (cm)	S_0	19.27	19.34	99.25	39.54
		S_1	17.19	17.77	93.59	34.27
		S_2	22.17	22.19	99.83	45.62
		S_3	39.85	39.91	99.72	81.98
3	Coleoptile length (cm)	S_0	29.31	29.71	97.28	59.54
		S_1	23.56	23.75	98.35	48.13
		S_2	20.27	20.54	97.32	41.92
4	Fresh weight of shoot per seedling (g)	S_0	26.67	26.68	99.93	54.92
		S_1	27.64	27.65	99.95	56.93
		S_2	29.29	29.30	99.93	60.31
		S_3	31.72	31.72	99.94	65.31
5	Fresh weight of root per seedling (g)	S_0	57.47	57.48	100.00	118.40
		S_1	58.59	58.59	100.00	120.69
		S_2	55.84	55.84	100.00	115.04
		S_3	53.37	53.37	100.00	109.95
6	Dry weight of shoot per seedling (g)	S_0	72.60	72.65	99.85	149.44
		S_1	89.89	89.89	100.00	185.17
		S_2	75.17	75.17	100.00	154.85
		S_3	64.81	64.81	100.00	133.51
7	Dry weight of root per seedling (g)	S_0	118.99	118.99	100.00	245.11
		S_1	146.31	146.31	99.99	301.38
		S_2	116.79	116.80	99.98	240.56
		S_3	103.45	103.47	99.96	213.07
8	Ratio of fresh weight of shoot to fresh weight of root	S_0	53.57	53.57	99.99	110.34
		S_1	62.40	62.40	99.99	128.53
		S_2	64.14	64.14	99.99	132.11
		S_3	85.47	85.47	99.99	176.06
9	Ratio of dry weight of shoot dry weight of root	S_0	79.83	79.86	99.93	164.39
		S_1	102.03	102.99	98.15	208.23
		S_2	75.45	75.53	99.80	155.27
		S_3	83.63	84.63	97.65	170.25

affected by salinity levels. Whereas some characters had high heritability in specific environment such as seedling height in S0, S1 and S3 and for ratio of dry weight of shoots to dry weight of roots in S0 and S2 which indicated that the inheritance of these traits was affected by salinity. These results were in accordance with the finding of Maiti *et al*. (1994).

The ultimate aim of studying the variability and heritability of any trait is to have an idea about the efficiency with which it can be improved by selection. The genetic gain was high for dry weight of root per seedling in all the four salinity levels, whereas, it was high for ratio of dry weight of shoots to dry weight of roots in S1.

On the basis of above discussion about GCV, heritability and genetic gain, it can be concluded that the experimental material of this study possessed potential for improvement in dry weight of root per seedling as the estimates of GCV, heritability and genetic gain were high in this character in all the four salinity levels. Therefore, selection is amicable in all the four salinity levels. Whereas, for ratio of dry weight of shoots to dry weight of roots, it is amicable only in S1 as estimates of these three parameters, *viz.*, GCV, heritability and genetic gain were higher in S1 salinity level only.

Salinity tolerance, being complex character, is difficult to improve by direct selection. The efficiency of selection can be increased by simultaneous selection for

Table 3. Correlation matrix for different traits in sorghum

S.No.	Character	Correlation coeficient (r)	Seeedling height	Coleoptile length	Fresh weight of shoots per Seedling	Fresh weight of roots per seedling	Dry weight of shoot per seedling	Dry weight of roots per seedling	Ratio of fresh weight of shoots fresh weight of roots	Ratio of dry weight of shoot
1	Germination percentage	g	0.23*	-0.09	0.35**	0.09	0.39**	0.25*	-0.00	0.16
		p	0.12	-0.09	0.23*	0.04	0.09	0.08	0.02	-0.05
2	Seedling height	g		-0.39**	0.24*	0.07	0.14	0.11	0.18	-0.02
		p		-0.44**	0.14	0.04	0.10	0.4	-0.01	0.04
3	Coleoptile length	g			-0.13	-0.03	-0..08	-0.16	-0.07	-0.13
		p			-0.08	0.03	-0.04	-0.03	-0.03	-0.02
4	Fresh weight of shoots per seedling	g				0.25*	0.76**	0.09	0.43**	0.58**
		p				0.19	0.40**	0.04	0.26**	0.25**
5	Fresh weight of roots per seeding	g					0.15	0.03	-0.06	-0.13
		P					0.19	0.06	-0.62**	0.03
6	Dry weight of shoots per seedling	g						0.03	0.40**	0.73**
		p						-0.00	-0.01	0.64**
7	Dry weight of roots per seedling	g							0.02	-0.38**
		p							-0.07	-0.24**
8	Ratio of fresh weight of shoot to fresh of root	g								0.47**
		p								0.19

g=Genotypic Correlation Coefficient , p=Phenotypic Correlation Coefficient

few correlated characters. In present study, the trend of genotypic and phenotypic correlation was similar between different characters (Table 3). However, the genotypic correlation coefficients were slightly higher than the corresponding phenotypic correlation coefficients. This indicated the role of environment on the association between characters.

Perusal of correlation across the environments showed that germination percentage was positively and significantly correlated with fresh weight of shoots per seedling, dry weight of shoot per seedling and dry weight of roots per seedling; seedling height with fresh weight of shoots per seedling, fresh weight of shoots per seedling with fresh weight of roots per seedling, dry weight of shoots per seedling, ratio of fresh weight shoots to fresh weight of roots; germination percentage and fresh weight of shoot per seedling was positive in all the four salinity levels. While seedling height was negatively and significantly correlated with coleoptiles length; fresh weight of roots per seedling with ratio of fresh weight of shoots to fresh weight of roots; and dry weight of roots per seedling to ratio of dry weight of shoots to dry weight of roots.

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