Combining Ability in Wheat for Seedling Traits by Line X Tester Analysis Under Saline Conditions

Muhammad Osaf*

Department of Botany, Government College University, Sarghod, Pakistan

Received: 23 July 2007. Accepted: 15 April 2009.

Abstract

A line × tester analysis involving five varieties SQ-26, SQ-77, GH-10, 8670, PARC-N_2 (lines) and three varieties 8721, SARC-5 and DN-4 (testers) were crossed to study some hydroponics growing characters. In controlled conditions SQ-26 exhibited the highest positive GCA effects on Shoot length, Shoot fresh weight, Na^+ and K^+ concentrations, while SQ-77 showed maximum GCA effects on Root length, Root fresh weight and Shoot dry weight in females and in males and both DN-4 and SARC-5 showed the highest GCA effects. Under high saline concentration female SQ-77 showed the maximum positive effects on all characters but on shoot length and Na concentration while male SARC-5 exhibited the highest positive GCA effects on all characters. Under high saline level, the cross combination SQ-26 × 8721 showed SCA effects for shoot length, whereas 8670 x 8721 showed the same effects for shoot fresh weight, root fresh weight and root dry weight. For Na^+ and K^+ concentrations, the cross combination GH-10 × DN-4 showed then highest SCA effects, whereas for shoot dry weight and root length, the cross combinations GH-10 × SARC-5 and PARC-N_2 × 8721 showed the highest SCA effects, respectively.

Key-words: combining ability, wheat, NaCl stress, salinity tolerance.

Introduction

The common bread wheat, one of the major crop, is widely grown not only in Pakistan but also throughout the world as a prime food cereal. In Pakistan it is used as the staple food of people and occupies a pivotal position in the economy as it covers the largest area with the highest production. Although the situation of wheat production in that country has been improved, yet consistent efforts are still needed to keep the pace with the ever increasing population. Nowadays, soil salinity is the most significant problem affecting crop production on irrigated land all over the world (Muralia et al., 1994) and it is also considered to be the major constraint for low crop production in arid and semiarid regions of Pakistan. Approximately, 6.67 mha of land in Pakistan are affected by salinity (Khan, 1998), which is about 1/3 of the total cultivated land in Pakistan.

The excessive accumulation of salts in semi arid soils and arid regions is a potential factor limiting productivity of irrigated agriculture. Low precipitations together with high evapotranspiration result in salt accumulation in the root zone that ultimately hinders plant growth (Sadat et al., 1999), and it is also known to affect seed germination, plant growth and reproduction with induced changes in anatomy and morphology of plants. A decline in total leaf area is often the first detectable response of salt stress in crops (Bradford and Hsiao, 1983). Increase in leaf area has been found to be more sensitive to salinity than either leaf emergence rate or dry matter accumulation (Curtis and Lauchli, 1995). Combining ability analysis provides useful information in this respect. The diallel analysis approach (Griffing, 1956) is beneficial when the number of parents involved is limited. Such diallel analysis gives poor estimates of genetic parameters because of the

* Corresponding Author: E-mail address: mosaf_1@yahoo.com

large sampling error, with the additional disadvantage that potentially superior parents are left un-tested. A way to sort it out outlies in the use of line x tester analysis of combining ability developed by Kempthorne (1957). Line × tester analysis can be efficiently used in order to evaluate large number of parents for general and specific combining ability. The selection and development of new genotypes of a particular crop is a continuous need due to natural segregation of parental characters. This situation necessitates a regular selection of new genotypes against salinity. The present study was planned to evaluate the wheat cultivars for combining ability and to collect some basic information on mutual relationship of some growing parameters under salinity stress conditions (Fooland et al., 1991). The studies thus clearly envisage it increasing the relative information source available on these characters which may be effectively used in designing future programs for the implement of salinity resistant wheat genotype.

Material and methods

Plant material: The experimental material consisted of five lines, SQ-26, SQ-77, GH-10, 8670, PARC-N_2 and three testers 8721, SARC-5, DN-4. The research work on combining ability was carried out in the experimental area of the Department of saline agriculture research centre, University of Agriculture, Faisalabad. The seeds of subscript F1 along with their parents were sown in sand soil in polyethylene lined iron trays in a triplicate randomized complete block design. At emergence, seedlings were sprinkled with half strength Hoagland's solution (Hoagland et al., 1950).

Transplanting: At two leaf stage (almost one week after emergence of seedling) the seedlings were transplanted from the iron trays to the 200 L capacity tubs. Two plants per hole of each genotype were transplanted into foam plugged holes in thermo pole sheets.

Developing the Salinity: After 3 days from transplanting, salinity was developed stepwise with NaCl reaching 10EC and 20EC levels. The pH was daily adjusted between 6.0 and 6.5 by adding HCl (IN) or NaOH (IN). Solutions were changed fortnightly during the entire experimental period.

Harvesting: Plants were harvested after eight week of salinity development. Plants were washed with distilled water and dried with blotting paper. At the time of harvesting, data were recorded about Shoot Length (cm), Root Length (cm), Shoot fresh weight (g), Root fresh weight (g) Shoot dry weight (g), Root dry weight (g).

Chemical Analysis: The youngest fully expanded leaf samples were collected in 1.5 cm^3 polypropylene tubes and stored at freezing temperature for chemical analysis. Frozen leaf samples in polypropylene tubes were thawed and crushed using a stainless rod with tapered end. The sap was collected in other polypropylene tubes by Gilson pipette and centrifuged at 6500 rpm for 10 minutes. The supernatant was collected and used for ionic analysis. The sap was diluted as required by adding distilled water. Sodium and potassium was determined using Sherwood-410 flame photometer.

Statistical Analysis: Combining ability studies were made by using line x tester analysis as described by Kempthorne (1957).

Results and discussion

General combining ability is the mean performance of a parent in a series of crosses of lines and testers. GCA estimate for all the characters under controlled conditions are given in table 1 to identify potentialities for sub-sequent breeding. With respect to shoot length, female parents SQ-26 and male parent SARC-5 showed a significant positive GCA (Ahsan et al., 1996). As regards to root length, positive GCA effects are more important and from this point of view SQ-26, SQ-77among females and DN-4 males are best general combiners with GCA. Out of eight parents, two females, SQ-26 and SQ-77, and one male, DN-4, showed significant positive GCA about shoot fresh weight. About root fresh weight, SQ-26 and SQ-77 among females with GCA, and DN-4 among males, showed positive significant GCA values (Kingsbury et al., 1984 and Palve et al., 1987). Therefore shoot dry weight SQ-26, SQ-77 exhibited significant positive GCA values in females and DN-4 with significant positive effects. As regards to root dry weight, the suitable parents were GH-10 and SARC-5 as they indicate significant positive GCA value (Nevo et al., 1992). While about Na

Table 1. Estimates of GCA for various seedling traits in bread wheat under non saline conditions.

Females	Shoot length	Root length	SFW	RFW	SDW	RDW	Na^+	K^+
SQ-26	2.866	3.363	1.551	0.548	0.085	-1.560	7.874	3.288
SQ-77	0.644	7.111	1.341	0.559	0.133	0.780	0.687	1.288
GH-10	-1.355	-5.111	-0.554	-0.0813	-0.009	1.755	7.820	0.288
8670	-2.577	-5.000	-1.650	-0.424	-0.104	0.975	-6.499	-2.155
PARC-N_2	0.422	-0.333	-0.688	-0.592	-0.105	-1.950	-9.936	-2.711
Standard Error	2.50	2.086	1.278	0.418	0.082	1.250	6.677	2.182
Males								
8721	0.156	-2.444	-0.825	-0.176	-0.032	-0.624	2.500	-1.756
SARC-5	1.689	-0.644	-0.156	-0.196	-0.050	0.956	-3.687	0.844
DN-4	-1.844	3.089	0.980	0.372	0.082	-0.332	1.187	0.9115.
Standard Error	1.137	2.813	0.90	0.324	00.70	0.518	7.21	0.112

and K concentrations the best results were obtained by female parents SQ-26 and GH-10 and male parents 8721. About Na+ concentration, female parents SQ-26 , and SARC and DN-4 male parents about K+ concentration indicate positive significant GCA effects (Singh et al., 1997). The values given in table 2 reveal that under low salinity level SQ-26, SQ-77 female parents showed significant positive GCA effects on shoot length, root length, shoot fresh weight, root fresh weight and shoot dry weight respectively, and male parents SARC-5 on shoot length, while DN-4 on root length, shoot fresh weight, root fresh weight and in shoot dry weight as they indicate significant positive GCA effects (Babu et al., 1995). In case of root dry weight female parents GH-10, 8670 and male parent DN-4 showed the significant positive GCA values (Suresh et al., 2001). As regards to the Na+ and K+ concentration SQ-26, SQ-77 among females while SARC-5 among male parents are the best general combiners with significant GCA values (Botella et al., 1997). In case of high saline level as in table 3, one female SQ-26 and two male SARC-5 and DN-4 out of eight parents showed positive significant GCA effects on shoot fresh weight. About the root fresh and dry weight, females parents SQ-26 and SQ-77 showed positive GCA effects while among male parents SARC-5 has a significant positive GCA effects. As regards to shoot dry weight and K+ concentration, the female parents SQ-77 showed the significant positive GCA effects, while GH-10 was the best about Na^+ concentration. Among male parents and about shoot dry weight, K^+ and Na^+ concentration, SARC-5 indicates significant positive GCA effects (Yogita et al., 1998).

The performance of the parents in the direct cross combinations for various traits in non-saline conditions are given in table 4. The cross combinations SQ-77 × DN-4 has the highest significant positive SCA values for shoot length. The combination SQ-26 × SARC-5 showed good specific

Table 2. Estimates of GCA for various Seedling traits in bread wheat at EC 10 dS/m.

Females	Shoot length	Root length	SFW	RFW	SDW	RDW	Na^+	K^+
SQ-26	5.933	1.353	1.191	0.129	0.019	-3.398	8.623	1.666
SQ-77	8.488	1.666	1.610	0.170	0.074	-13.371	7.124	2.333
GH-10	-4.288	-1.084	-0.398	-0.106	-0.020	8.052	7.874	-1.000
8670	-5.733	-1.246	-1.335	-0.127	-0.032	5.097	-14.623	-3.660
PARC-N_2	-4.400	-0.089	-1.060	-0.066	-0.040	3.620	-8.998	0.666
Standard Error	4.04	1.294	1.042	0.024	0.010	4.207	7.28	2.11
Males								
8721	-1.733	-0.632	-0.628	-0.40	-0.018	-4.728	1.650	-0.111
SARC-5	1.800	-0.078	0.231	-0.028	-0.008	0.148	4.199	0.956
DN-4	-0.067	0.710	0.398	0.068	0.025	4.580	2.550	-0.844
Standard Error	1.777	0.467	0.262	0.043	0.017	2.426	2.633	0.894

Table 3. Estimates of GCA for various Seedling traits in bread wheat at EC 20 dS/m.

Females	Shoot length	Root length	SFW	RFW	SDW	RDW	Na^+	K^+
SQ-26	1.244	0.480	-0.067	0.058	-0.058	0.0200	0.883	-2.613
SQ-77	1.133	0.972	0.608	0.150	0.150	0.074	-1.039	2.963
GH-10	-2.311	-0.550	-0.290	-0.082	-0.082	-0.043	3.769	0.799
8670	-0.422	-0.794	-0.399	-0.105	-0.105	-0.031	1.728	0.133
PARC-N_2	0.355	-0.108	0.148	-0.020	-0.020	-0.020	-5.342	-1.281
Standard Error	1.179	0.693	0.588	0.103	0.137	0.063	2.256	2.847
Males								
8721	-0.356	-0.152	-0.410	-0.047	-0.047	-0.024	-1.710	-0.266
SARC-5	0.978	0.391	0.219	0.079	0.079	0.030	1.438	0.283
DN-4	0.622	-0.239	0.191	-0.032	-0.032	-0.006	0.272	-0.017
Standard Error	0.637	0.269	0.156	0.067	0.066	0.029	1.110	0.229

Table 4. Estimates of SCA for various Seedling traits in bread wheat under non saline conditions.

Genotypes	Shoot length	Root length	SFW	RFW	SDW	RDW	Na^+	K^+
SQ-26 × 8721	-1.266	-2.666	-0.675	-0.129	-0.083	-0.546	6.561	2.311
SQ-26 × SARC-5	-0.466	7.200	0.579	0.264	0.074	-1.248	-3.187	-1.955
SQ-26 × DN-4	1.733	-4.533	0.096	-0.134	0.008	1.794	-3.374	-0.355
SQ-77 × 8721	0.288	1.888	0.724	0.236	0.132	0.0390	-1.249	-0.022
SQ-77 × SARC-5	-4.911	-5.244	-1.794	-0.430	-0.119	1.384	5.874	-0.622
SQ-77 × DN-4	4.622	3.355	1.069	0.194	-0.012	-1.423	-4.624	0.644
GH-10 × 8721	-2.044	6.111	0.333	0.164	0.054	-1.813	13.123	1.311
GH-10 × SARC-5	2.755	-2.022	0.017	-0.146	-0.030	2.164	1.499	-1.288
GH-10 × DN-4	-0.711	-4.088	-0.351	-0.018	-0.023	-0.351	-14.623	-0.022
8670 × 8721	2.844	1.000	0.353	0.244	0.033	2.476	-14.685	-0.244
8670 × SARC-5	3.311	-3.133	0.324	-0.059	0.011	-2.028	2.749	2.488
8670 × DN-4	-6.155	2.133	-0.677	-0.184	-0.044	-0.448	11.936	-2.244
PARC-N_2 × 8721	0.177	-6.333	-0.735	-0.514	-0.136	-0.156	-3.749	-3.355
PARC-N_2 × SARC-5	-0.688	3.200	0.872	0.371	0.064	-0.273	-6.936	1.377
PARC-N_2 × DN-4	0.511	3.133	-0.136	0.143	0.072	0.429	10.686	1.977
Standard Error	4.195	7.170	1.005	0.274	0.127	2.361	12.57	2.324

combining ability for root length. In case of shoot fresh weight, the cross SQ-77 × DN-4 was the one with significantly highest values (Mass et al., 1989a). The combination of PARC-N_2 × SARC-5, SQ-77 × 8721, 8670 × 8721,GH-10 × 8721 and 8670 × SARC-5, exhibited best specific combining ability for root fresh weight, shoot dry weight, root dry weight, Na^+ and K^+ concentration (Abdel et al., 1992 and Prakash et al., 1992).

The table 5 depicts specific combining ability effects in 10 dSm.1 and reveals that the combinations SQ-77 x DN-4 showed best significant positive combining ability for shoot length, root length, shoot fresh weight, root fresh weight and shoot dry weight (Afiah et al., 1999). The combinations 8670 × SARC-5 had superior estimates for root dry weight. The combinations with the highest values namely 8670 X SARC-5, SQ-77 X DN-4 exhibited best specific combining ability for Na^+ and K^+ (Flowers et al., 1995 and Subhadra et al., 2000).

Table 6 describes estimates of specific combing abilities for various traits in 20dSm^{-1}. The performance of the varietal combination SQ-26 × 8721 showed significant positive value in shoot length, while 8670 × 8721 had the best specific combining ability for root length, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight. GH-10 × SARC-5 had significant positive value with respect to Na^+ and K^+ (Kathiria et al., 1996 and Khan et al., 2003). From the results of the experiments, it is suggested that among females SQ-77 was the best line. Similarly, among males SARC-5 were the best general combiners. While the cross combinations 8670 × 8721 and SQ-77 × DN-4 were found suitable crosses in high saline level for further breeding programs.

Table 5. Estimates of SCA for various Seedling traits in bread wheat at EC 10 dS/m.

Genotypes	Shoot length	Root length	SFW	RFW	SDW	RDW	Na^+	K^+
SQ-26 × 8721	3.733	0.675	0.306	0.011	-0.024	12.485	-8.399	1.333
SQ-26 × SARC-5	1.866	0.134	0.203	0.082	0.055	-14.553	9.823	-14.000
SQ-26 × DN-4	-5.600	-0.810	-0.509	-0.093	-0.030	2.068	-1.424	0.066
SQ-77 × 8721	-13.488	-1.870	-0.869	-0.236	-0.053	14.701	-8.024	-2.666
SQ-77 × SARC-5	2.977	0.219	-0.162	-0.035	-0.023	-1.255	7.949	-1.066
SQ-77 × DN-4	10.511	1.650	1.031	0.272	0.077	-13.445	0.075	3.733
GH-10 × 8721	4.955	0.840	-0.956	0.113	0.008	-5.614	1.349	-0.333
GH-10 × SARC-5	-0.244	0.346	-0.159	0.027	0.065	11.672	-2.924	0.933
GH-10 × DN-4	-4.711	-1.186	-0.796	-0.141	-0.074	-6.057	1.574	-0.600
8670 × 8721	4.066	-0.427	0.072	0.131	0.024	-20.390	13.723	1.666
8670 × SARC-5	-4.800	-0.621	-0.483	-0.044	-0.052	14.627	-6.299	1.933
8670 × DN-4	0.733	1.049	0.410	-0.086	0.028	5.762	-7.424	-3.600
PARC-N_2 × 8721	0.722	0.782	-0.466	-0.019	0.045	-1.182	1.349	0.005
PARC-N_2 × SARC-5	0.200	-0.078	0.601	-0.029	-0.044	-10.490	-8.548	-0.400
PARC-N_2 × DN-4	-9.333	-0.703	-0.135	-0.031	-0.007	11.672	7.199	0.4000
Standard Error	7.390	1.380	1.002	0.238	0.073	14.213	10.324	3.181

Table 6. Estimates of SCA for various Seedling traits in bread wheat at EC 20 dS/m.

Genotypes	Shoot length	Root length	SFW	RFW	SDW	RDW	Na^+	K^+
SQ-26 × 8721	2.022	0.201	-0.064	-0.083	0.064	0.019	1.474	2.264
SQ-26 × SARC-5	-0.311	0.042	0.193	0.174	-0.008	0.006	-2.936	0.715
SQ-26 × DN-4	-1.711	-0.244	-0.128	-0.090	-0.056	-0.025	1.462	-2.979
SQ-77 × 8721	-1.200	-1.202	-0.466	-0.485	-0.187	-0.075	-2.027	-3.562
SQ-77 × SARC-5	-0.200	0.661	0.227	0.208	0.063	0.028	-1.720	-1.115
SQ-77 × DN-4	1.400	0.541	0.238	0.277	0.124	0.046	3.748	4.678
GH-10 × 8721	-0.422	-0.297	0.109	0.0900	0.001	0.003	-4.866	-1.648
GH-10 × SARC-5	0.911	0.176	0.059	0.040	0.015	-0.007	6.562	4.794
GH-10 × DN-4	0.488	0.120	-0.168	-0.130	-0.016	-0.002	-1.696	-3.146
8670 × 8721	-0.977	0.634	0.734	0.715	0.094	0.050	0.689	1.265
8670 × SARC-5	1.022	-0.262	-0.208	-0.227	-0.021	-0.019	4.603	-1.531
8670 × DN-4	-0.044	-0.372	-0.526	-0.488	-0.073	-0.003	-5.292	0.266
PARC-N_2 × 8721	0.577	0.664	-0.313	-0.236	0.026	0.003	4.730	1.681
PARC-N_2 × SARC-5	-1.422	-0.618	-0.272	-0.196	-0.049	-0.014	-6.508	-2.863
PARC-N_2 × DN-4	0.844	-0.045	0.585	0.432	0.022	0.011	1.778	1.182
Standard Error	2.009	0.621	0.620	0.644	0.088	0.040	6.410	4.698

Keeping in view the increasing demand for more food supply needed for the growing population, development of research programmers aimed to exploring new genetic resources is being emphasizes in these days. Whereas soil salinity is a limiting factor in allowing exploitation of crops in many parts of the world, and as an increasing phenomenon particularly in arid and semi arid areas, it poses a great threat to the survival of human populations in those areas.

The suggested biotic approach to this problem that allows the use of salty areas for cultivation in its essence requires improvement in the salinity tolerance of existing crop species so that they may be successfully grown in saline soils.

References

Abdel-Aleem M.M.M., Sabry S.R.S., Hanna N.S. 1992. Seedling characteristics as selection criteria for salinity tolerance in wheat. Rachis, 11(1/2):33-41.

Afiah S.A.N., Kishk E.T., Abdel-Hakim A.M. 1999. Genetic analysis of yield and its attributes under two salinity levels in bread wheat (*Triticum aestivum* L.). Annals Agri. Sci., Cairo, 44(1):309-336.

Ahsan M., Wright D., Vrik D. 1996. Genetic analysis of salt tolerance in spring wheat (*Triticum aestivum* L.). Cereal Res. Commun., 24(3):353-360.

Babu V.R., Kumar S.S. 1995. Combining ability analysis for wheat in normal and stress environments. Annals Agri. Res., 16(1):23-27.

Flowers T.J., Yeo A.R. 1995. Breeding for salinity resistance in crop plants: where next? Aust. J. Pl. Phys., 22:875-884.

Fool M.R., Jones R.A. 1991. Genetic analysis of salt tolerance during germination in Lycopersicon. Theor. Appl. Genet., 81:321-326.

Gupta Y., Sastry E.V.D. 1998. Effect of salinity on combining ability in wheat (*Triticum aestivum*). Ind. J. Agri. Res., 32(2):139-143.

Hoagland D.R., Arnon D.I. 1950. The water culture method for growing plants without soil. Agric. Exp. Sta. Univ. Calif. Circular No. 347.

Kathiria K.B., Sharma R.K. 1996. Combining ability analysis for earliness in breadwheat (*Triticum aestivum* L. Em. Thell) under normal and salt affected soils. Ind. J. Genet. Plant Breed., 56(2):196-201.

Khan A.A., Rao S.A., McNeilly T. 2003. Assessment of salinity tolerance based upon seedling root growth response functions in maize (*Zea mays* L.). Euphytica, 131:81-89.

Khan A.S., Asad M.A., Ali Z. 2003. Assessment of genetic variability for NaCl tolerance in wheat. Pak. J. Agri. Sci., 40(1):33-36.

Kingsbury R.W., Epstein E., Pearcy R.W. 1984. Physiological responses to salinity in selected lines of wheat. Pl. Physiol., 74:417-423.

Maas E.V., Poss J.A. 1989a. Salt sensitivity of wheat at various growth stages. Irrig. Sci., 10:29-40.

Muralia S., Sastry E.V.D. 1994. Stability analysis in wheat (*Triticum aestivum*) for seedling emergence and establishment characters at different salinity levels. Ind. J. Genet. and Plant Breed., 54:351-356.

Nevo E., Gorham J., Beiles A. 1992. Variation for Na^+ uptake in wild emmer wheat, *Triticum dicoccoides* in Israel: Salt tolerance resources for wheat improvement. J. Exptl. Bot., 43:511-518.

Plave S.M., Thete R.Y., Dumber A.D. 1987. Combining ability in wheat from line × tester analysis. Maharashtra Agri. Univ. J., 12(2):244-245.

Prakash V., Sastry E.V.D. 1992. Effects of salinity on germination and seedling growth in wheat. Ann. Arid Zone, 31(1):71-72.

Qureshi R.H., Rashid A., Ahmed N. 1990. A procedure for quick screening of wheat cultivars for salt tolerance. In: B.C. Loughman (ed.): Genetic Aspects of Plant Mineral Nutrition, 315-324. Kluwer Academic Pub., Amsterdam.

Sadat S.A., McNeilly T. 1999. Assessment of variability in salt tolerance in diploid *Aegilops* ssp. J. Genet. & Breed., 53:183-188.

Salam A., Hollington P.A., Gorham J., Wyn Jones R.G., Gliddon C.J. 1999. Physiological genetics of salt tolerance in (*Triticum aestivum* L.): Performance of wheat varieties, inbred lines and reciprocal F_1 hybrids under saline conditions. J. Agron. & Crop Sci., 183:145-156.

Singh K.N., Chatrath R. 1997. Combining ability studies in breadwheat (*Triticum aestivum* L. Em Thell) under salt stress environments. Ind. J. Genet. Plant-Breed., 57(2):127-132.

Singh S., Singh M. 2000. Genotypic basis of response to salinity stress in some crosses of spring wheat (*Triticum aestivum* L.) Euphytica, 115(3):209-214.