Int. J. Environ. Res., 2(2): 125-132, Spring 2008
ISSN: 1735-6865

Genotypic X Environmental Interaction of Cowpea Genotypes

Yousaf, A.* and Sarwar, G.

Nuclear Institute for Agriculture and Biology (NIAB), P.O. Box No. 128,
Faisalabad, Pakistan

Received 13 July 2007; Revised 15 Nov. 2007; Accepted 7 Dec. 2007

ABSTRACT: Twenty four Cowpea varieties were raised at NIAB and ARRI, Faisalabad selected for plant height (42-136cm) days taken to 95 % flowering (62-79 days) and for diseases resistance (0.67-7 rating). Infestation was maximum on IT-97K-461-4, 1068-7, IT-97K 1042-8 and IT-98k-558-1 and was graded as susceptible. Maximum grain yield was recorded in Elite (649 kg/ha) and lowest grain yield was observed in IT-95K-1156-3 (332.3 kg/ha). Yield and yield contributing characters of twenty four entries tested revealed that they differ significantly from each other. The stability parameters for 12 locations indicated that the interaction was of cross over nature because the ranking of mean seed yield at 12 locations was dissimilar except NCP-1 which stood first at all the 12 locations. Regression coefficient of the six genotypes was non significant from zero. Standard deviation to regression S^2d was also non significant except IT-97k-1042-8 genotype Elite with second highest yield performance had 0.982 non significant value of b near to unity and non significant S^2d almost equal to zero (0.001). In addition to Elite the highest yielding line NCp-1 also showed stability because it had non significant regression coefficient (b) value from unity and non significant standard deviation to regression (S^2d) from zero.

Key words: Cowpea, Yield, Yellow Mosaic Virus, Agronomic Characters, Genotypes, Stability

INTRODUCTION

The cowpea (*Vigna unguiculata. L*) commonly known as Lobia is an annual legume. This important tropical and subtropical legume is grown for forage green pods and grains. It is an excellent source of protein. White seeded varieties and black eyed types are commonly grown for grain and table use. While ving varieties that mature late are preferred for forage cowpea and can be grown on wide range of soil types and under a diversity of climatic and cultural condition. Highest yields of forage are obtained in sandy loam soils supplemented with proper irrigation. However, for seed purpose, cowpea reasonably performs well on soil with low fertility. High rates of nitrogen and excessive moisture are detrimental and can result in excessive vegetative growth, delayed maturity and shattering.

In Pakistan cowpea is grown on an area of approximately 9 thousand hectares with an annual production of 4.9 thousand tones (Anonymous 2004). This poor yield may be due to unavailability of high yielding and stable genotypes along with appropriate advance agronomic management practices. To bridge the yield gap improvement in yield and yield components, plant architecture require drastic change. For this mutation breeding and other related techniques are to be employed for widen the genetic base.

Out of 20.2 million hectares of cultivated land in Pakistan, 6.8 million hectares are affected with salinity. Out of this, the affected area in Punjab province is 2.67 million hectares. The salinity area has been categorized into four major classes namely very severe saline lands (652 thousands hectares), severely saline (738.3 thousands hectares), moderately saline (804.8 thousands hectares) and slightly saline area (472.4 thousands hectares).

Pakistan is seriously facing water scarcity problem both for irrigation and drinking.

*Corresponding author: Email-yousaf_sem@yahoo.com

Moreover, almost 70 % of the groundwater available contains moderate to high concentration of salts. The condition is alarming as it has created a situation of crises in the country. Reclamation, drainage and water management can minimize the extent and spread of saline soils, however engineering and management costs are high. Therefore, new strategies to cope with salinity problem are essential.One example of new strategy is breeding crops for increased salt tolerance. It is possible to improve the genetic tolerance of wheat crop to salinity and thereby increase the productivity of marginal lands. Efforts to breed for salinity tolerance are slow due to limited knowledge of genetics of tolerance, inadequate screening techniques, low selection efficiency and poor understanding of salinity and environmental interaction.

It is now well established that some plant species can tolerate high salinity (Glenn, *et al.* 1996. Rehman, *et al.*1998). Significant differences in their *character effectiveness* have also been reported among varieties of different species including wheat (Akhtar *et al.* 1994, 1998. Saqib *et al.* 1999) and cotton (Qadir and Shams, 1997, Ashraf and Ahmad, 2000).The differential behavior of plant species may be helpful for exploitation of these soils by growing fairly tolerant genotypes. This paper reports the results of different studies pertaining to preliminary evaluation for disease reaction and for yield and yield contributing characters and field performance of six yielding cowpea genotypes in different ecological zones of the Punjab province under natural saline field condition. These studies would help to identify genotypes with high yield along with their better adaptively in different saline environments.

MATERIALS & METHODS

Cowpea varieties were evaluated during the post-rainy season after maize at the two different locations of Ayub Agriculture Research Institute, Faisalabad (AARI) and Nuclear Institute of Agriculture and Biology, Faisalabad (NIAB) during the last week of August, 2001 (Table 1). Due to insufficient seeds, each cu1tivar was planted only in 4 rows of 5 m long. Cultivars were planted at 15 cm plant to plant 30 cm row to row distance. Fertilizer at the rate of 20: 20: 20 kg/ha N_2, P_2O_5 and K_2O were applied before planting. Insect pests and diseases were recorded throughout the cropping period. Scoring of yellow mosaic virus (YMV) was recorded as mentioned by Shukla (1978) on 4-5 week old plants. Agronomical data such as number of days to 95 % flowering, 95 % maturity, plant height (cm), number of pods per plant, number of seeds per pod and pod length was recorded (Table 2). Green pod yield (kg/ha), grain yield kg/ha and dry biomass yield (kg/ha) was recorded in few entries (Table 3), from the two control rows while the green pod yield was recorded from the other two rows grown under normal field conditions.

Six cowpea cultivars were tested in the natural saline fields of district Faisalabad, Toba Tek Singh and Jhang at twelve different locations during the years 2003-2004 and 2004-2005. Experiments were sown in RCB design in four replications. Soil samples were collected from 0-15 and 16-30cm depth before sowing and after harvesting of the crop. The physico chemical analysis of 0-15 cm soil was (pH = 8.37, EC 7.19 d/Sm and SAR = 26.24) where as 16-30 cm soil had (pH = 9.32, EC 14.6 dSm-1 and SAR = 49.88) average of all locations. At maturity, grain yield was recorded and subjected to analysis of variance (Steel and Torrie 1980) and stability parameters following Eberhart and Russell model (1966).

RESULTS & DISCUSSION

The data on plant height and other agronomic characters of two experiments are presented in Table 1. Plant height ranged from 42.33-137.6 cm. Yellow mosaic virus infection score was between 0.66-7.00, days taken to 95% flowering were from 61.6-79.0, numbers of pods per plant were observed from 12.6-17.0, and numbers of seeds per pod were from 7.6-11.3 and pod length ranged from 8.3-12.0 cm. Significant differences was observed for plant height, yellow mosaic virus infection and days taken to 95 % flowering in the twenty four test entries where as number of pods per plant seeds per pod and pod length (cm) were non-significant.

Table l. Agronomic Characters of Twenty Four Cowpea Genotypes

No.	Variety Name	Plant height (cm)	Yellow mosaic virus (score)	Days taken to 95 % flowering	No. of pods per plant	No. of seeds per pod	Pod length (cm)
301	1T-97k-461-4	106.6	7.00	65.3	15.00	10.3	12.00
302	1T-98k-469-11	86.00	6.3	64	12.6	10.3	11.00
303	1T-97k-1068-7	128.00	7.00	62	16.3	9.6	9.00
304	1T-94k-440-3	116.3	5.3	65	15.00	9.00	8.6
305	1T-95k-627-34	79.3	5.6	64.33	15.6	11.3	8.6
306	1T-95k-1093-5	135.6	6.3	62.66	15.3	10.00	9.00
307	1T-97k-1021-15	129.3	7.00	66.3	15.3	9.00	8.6
308	Lobia-2000	101.3	5.00	64.3	15.00	9.6	9.3
309	1Tk-238-3	117.6	5.00	61.6	15.6	9.6	11.00
310	1T-98k-463-6	104.6	6.3	68.6	15.00	10.3	11.00
311	1T-97k-529-14	77.3	6.3	63.00	15.00	7.6	10.6
312	1T-98k-558-1	44.3	7.00	63.00	16.00	11.3	9.6
313	1T-95k-1156-3	62.6	2.3	73.3	13.3	9.00	10.6
314	1T-94k-137-6	86	2.00	79.00	14.00	10.00	10.00
315	1T-97k-1042-8	71.6	1.66	71.00	14.3	9.6	11.3
316	1T-97k-499-4	70.6	2.00	71.0	15.6	8.00	9.3
317	1T-97k-497-2	54	1.00	65.00	14.3	8.00	9.3
318	1T-93k-452	113	1.00	64.00	14.6	11.3	8.3
319	1T-97k-350-4	137.6	1.00	74.00	15.3	8.6	9.3
320	S.A Dandy	66	1.00	64.3	15.00	9.6	10.00
p-518	P-518	127.3	1.00	67.3	17.00	10.6	10.3
Elite	Elite	46.33	1.00	68.6	15.00	11.00	9.00
No.44	No.44	52	1.00	75.6	16.00	8.6	9.00
It-84-552	It-84-552	42.33	0.66	77.00	16.3	9.6	9.33

Table 2. Agronomic Characters of Twenty Four Cowpea Genotypes

No.	Variety Name	Plant height (cm)	Days Taken To 95 % Flowering	Disease Reaction
301	1T-97k-461-4	106.7 BCD	65 EFJ	7.0 A
302	1T-98k-469-11	86.00 DEFG	64 FJ	6.3 AB
303	1T-97k-1068-7	128.00 ABC	62 G	7.0 A
304	1T-94k-440-3	116.3 ABC	65 FG	5.3 AB
305	1T-95k-627-34	79.3 EFGH	64 FG	5.6 AB
306	1T-95k-1093-5	135.7 A	63 FG	6.3 AB
307	1T-97k-1021-15	129.3 AB	66 DEFG	7.0 A
308	Lobia-2000	101.3 CDEF	64 FJ	5.0 B
309	1Tk-238-3	117.7 ABC	62 G	5.0 B
310	1T-98k-463-6	104.7 BCDE	69 CDEFG	6.3 AB
311	1T-97k-529-14	77.3 FGHI	63 FG	6.3 AB
312	1T-98k-558-1	44.3 KL	63 FG	7.0 A
313	1T-95k-1156-3	62.67 GHIJKL	73 ABCDE	2.3 C
314	1T-94k-137-6	86.00 DEFG	79 A	2.0 C
315	1T-97k-1042-8	71.67 GHIJK	71 BCDEF	1.6 C
316	1T-97k-499-4	70.67 GHIJK	71 BCDEF	2.0 C
317	1T-97k-497-2	54.00 HIJKL	65 FG	1.0 C
318	1T-93k-452	113.00 ABC	64 FG	1.0 C
319	1T-97k-350-4	137.7 A	74 ABCD	1.0 C
320	S.A Dandy	66.00 GHIJKL	64 FG	1.0 C
p-518	P-518	127.3 ABC	67 DEGF	1.0 C
Elite	Elite	46.3 JKL	69 CDEFG	1.0 C
No.44	No.44	52.00 IJKL	76 ABC	1.0 C
It-84-552	It-84-552	42.3 L	77 AB	0.66 C

In a column means followed by the same letter are not significantly different at 5 % level of DMRT

Table 3. Mean Grain Yield and Other Agronomic Characters of six Varieties of Cowpea

Varieties	Grain yield (kg/ha)	Green pod yield (kg/ha)	Biomass yield (kg/ha)
Elite	648.7 A	1088 D	766.7 A
S.A Dandy	396.0 C	1401 A	671.7 B
1T-97k-497-2	550.7 B	1425 A	622.3 BC
1T-97k-499-4	370.7 CD	1342 B	591.3 CD
1T-97k-1042-8	545.0 B	1153 C	549.3 D
1T-95k-1156-3	332.3 D	1021 E	456.3 E

In a column means followed by the same letter are not significantly different at 5 % level of DMRT

Aphid *(Aphis craccivora),* pod sucking bug (*Riptortus* sp.) and tobacco caterpillar (*Spodoptera litura*) were identified as major insect pests, while grasshoppers were recorded as minor insect pests on this crop. The aphids were serious before and after flowering, while thetobaccocaterpillar was serious during the early growth stage of the crop. The pod sucking bug did a considerable damage on young pods, which could not develop well, the infested grains were so shriveled and hence were useless for human food and animals feed.

Reaction of 24 genotypes of cowpea cultivars to yellow mosaic virus disease varied at both locations. It is evident from the data that cowpea genotypes under study vary in reaction against yellow mosaic virus disease (Table 1). Genotypes IT-97K-461, IT-97-K-1021-15 showed moderately tolerant to susceptible reaction and IT-95-1156-3, IT-94K-137-6, IT-97K-1042-8,IT-97K-499-4, IT-97K-497-2, IT-93K-452, IT-97K-350-4, SA dandy, P-518, Elite, No.44 and IT-84-552 showed highly resistant to resistant reaction . Cowpea has the distinction of carrying more seed borne viruses than any other crop species (Hampton, 1983). Establishment and distribution of virus free cowpea breeding material and germplasm is suggested to control or avoid the introduction of new viruses (Bashir, *et al*., 1999). There are many other viruses i.e., BICMV, CABMV and potyviruses also virulent (Bashir and Hampton 1996a, Bashir and Hampton, 1996b, Latif, *et al.* 1999).Cowpea cultivars identified in this study have also higher yielding ability. Correa and Zeigler (1995) suggested that selecting high levels of resistance when diverse sources are combined can be used to develop a cultivar with stable resistance against diseases. Disease resistant and high yielding genotypes are being crossed to in corporate disease resistant into high yielding genotypes.

Maximum grain yield was recorded in Elite followed by 1 T -97K-497-2 and 1 T- 97K-1042-8 i.e.550.7 and 545 kg/ha respectively. Lowest grain yield was noted in 1 T- 95k-1156-3 which was only 332.3 kg/ha. Highest green pod yield was observed in 1 T- 97k-497-2 (1425) and S.A. Dandy 1401 kg/ha. Lowest green pod yield was noted IT -95k (l156-3 kg/ha). Maximum biomass was produced by Elite i.e. 766.7 kg/ha followed by S.A. Dandy and 1T-97k-497-2 (671.7) and 622.3 kg ha^{-1}. Lowest total dry biomass yield was noted in 1 T -95k-1156-3 (456.3 kg/ha yield, Table 3). Yield And yield attributing characters of twenty four cultivars tested reveal that they differed significantly from each other.

Combined analysis of variance (Tables 4 to 6) of cowpea at 12 naturally salt affected locations showed highly significant variance among varieties, locations and Var x Env interaction. This type of results proves the validity that data may be preceded further for estimating stability parameters.

The environment x genotypes interaction which was highly significant in this case may be either a cross over GxE interaction or a non cross over nature. In cross over type, significant change in ranks occurs from one environment to an other (Matus, *et al.,* 1997) and incase of non crossover type, the ranking of genotypes remains constant across different environment and the interaction is significant due to change in the magnitude of response (Baker, 1988, Matus, *et al.*, 1997).

In the present study the interaction was of crossover nature, because the ranking of mean seed yield at 12 locations was dissimilar except NCP-I which stood first at all the 12 locations. The maximum seed yield was obtained at L3 (998 kg/ha) followed by L2 (966 kg/ha) and L1and

L5 (925 kg/ha[1]). Genotype elite produced second highest yield at most of the locations but not at all locations overall highest seed yield (767 kg/ha) was achieved at L4 followed by L3 (762 kg/ha) and (L2 746 kg/ha). The lowest seed yield was collected from L12 (620 kg/ha) location.

Overall mean performance of 12 locations (Table 7) indicated the significant superiority of genotype NCP-1 by producing 879 kg/ha seed yield genotype Elite (739 kg/ha) produced the second highest seed yield followed by SA-Dandy (728 kg/ha). The lowest seed yield (558 kg/ha) was produced by IT-97k-1042-8. Genotype 82E-8 (675 kg/ha) and IT-97k-497-2 (603 kg/ha) along with IT-97k-1042-8 also produced less yield as compared to standard mean (697 kg/ha). All the genotypes under study showed non significant regression coefficient (bi) values.

Finaly and Wilkinson (1963) estimated for each variety a linear regression of its yield on the mean yield of all varieties for each locations. Accordingly, a stable variety is the one for which the regression coefficient does not differ significantly from zero (i.e. b = 0 wither the limit of sampling error) and thus stability is defined ad the consistency in performance of a variety over varying environment.

All genotypes except IT-97k-1042-8 showed non significant difference from zero in case of standard deviation to regression (Table 6). According to Eberhert and Russells Model (1966), b (regression coefficient) is considered as parameters of response and S^2d as the parameter of stability. For a given value of independent variable, the value for depend variable may be estimated by using the regression equation provided S^2d in not significantly different from zero.

Assuming $S^2d = 0$, a high value of b will mean more change in Y for a unit change in IJ. In other words, the variety is more responsive such variety may therefore, be recommended only for high favorable environments.

In this study genotype Elite second to be the most stable genotype which had 0.982 non significant value of b near to unity and non significant deviation to regression (S^2d) almost equal to zero (0.001). Genotype Elite also stood second position by producing 739 kg/ha seed yield.

The highest yielding line NCP-1 also showed stability because it had non significant regression coefficient and non significant standard deviation to regression (S^2d). Based on these data line Elite and NCP-1 may be regarded as most stable and adapted genotypes in a wide range of environments. Genotype IT-97k-1042-8 showed poor yield performance (558 kg/ha) as compared to standard mean (697 kg/ha) with non significant regression coefficient value but significant standard deviation to regression (S^2d). Hence this line may not be regarded as stable one stability parameters showing such type of results in different genotypes had been reported earlier in different field crops, such as lentil (Sarwar, *et al*., 2003), mungbean (Rajput, *et al*., 1986), wheat (Ali, *et al*., 2005).

CONCLUSION

We have a vigorous programme on selection of salt tolerant plants and utilization of these plants in saline lands. Cultivation of salt tolerant

Table 4. Combined analysis of variance for cowpea 2003-04 and 2004-05

Values	Source	Degree of freedom (d. f)	Sum of squares (s. s)	Mean square (m. s)	F value	Prob.
1	Replication	2	12024.843	6012.421	4.18*	0.0173
2	Factor A (Var.)	11	454169.718	41288.156	28.69 **	0.0000
4	Factor B (Env.)	5	2321631.579	464326.316	322.64**	0.0000
6	AB (Var.x Env.)	55	274899.144	4998.166	3.47**	0.0000
-7	Error	142	204359.824	1439.154		
	Total	215	3267085.106			

Table 5. Pooled analysis of variance for cowpea 2003-04 and 2004-2005

Source	Degree of freedom (d. f)	Sum of squares (s. s)	Mean square (m. s)	F. Value
Total	71	1.018	0.014	
Environments	11	0.152	0.014	
Varieties	5	0.774	0.155	108.871**
Varieties x Environment	55	0.092	0.002	
Environment + Varieties x Environment	66	0.244	0.004	
Environment (Lin)	1	0.152	0.152	
Varieties x Environment (Lin)	5	0.007	0.001	0.919NS
Pooled Deviation	60	0.085	0.001	0.946NS
Pooled Error	144	0.216	0.002	

Table 6. Stability parameter of cowpea genotypes tested under various environments

No.	Varieties Name	Mean Seed Yield (kg/ha)	Regression co-efficient (bi)	Standard deviation to regression (S^2d)
1	NCP-1	879A	1.219NS	0.002NS
2	ELITE	739B	0.982 NS	0.001NS
3	82-E-8	675C	1.020 NS	0.000NS
4	IT-97K-497-2	603D	1.271 NS	0.000NS
5	IT-97K-1042-8	558E	0.842 NS	0.003*
6	SA-DANDY	728B	0.666 NS	0.000NS
Standard Mean				

LSD 5% = 17.68
LSD 1% = 23.35

Table 7. Performance of cowpea genotypes in multilocational yield trails on naturally salt affected soils during the year 2003-04 and 2004-05

No.	Genotypes	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Mean
1	NCP-1	925A	966A	998A	914A	925A	856A	925A	797A	852A	770A	831A	793A	879
2	ELITE	757B	845B	799B	754B	730C	800B	757B	685BC	708B	665AB	694ABC	678C	739
3	82-E-8	685C	717C	701D	759B	700D	709D	686C	672C	654D	590B	674BCD	559D	676
4	IT-97K-497-2	595D	650D	672E	719BC	608E	679D	596D	558D	557E	547B	540D	515E	603
5	IT-97K-1042-8	504E	553E	622F	679C	506F	615E	504E	558D	472F	620B	603CD	465F	558
6	SA-DANDY	712BC	744C	779C	775B	772B	760C	676C	713E	682C	658AB	761AB	708B	728
	Mean	696	746	762	767	707	737	691	664	654	642	684	620	697

The physio chemical analysis of 0-15 cm soil was (pH = 8.37, EC 7.19 dSm-1 and SAR = 26.24) where as 16-30 cm soil had (pH = 9.32, EC 14.6 dSm-1 and SAR = 49.88) average of all locations.

crops species and utilization of land is therefore, a logical approach. We are trying to find out ways and means of gainful utilization of saline land and to increase per unit income by diversifying the cropping systems. Intercropping of cotton/ cowpea/mungbean led to increase the poor farmer's income and fertility of the soil was also enhanced. We are also trying to explore the possibility of amelioration of these lands through suitable culture practices and a combination of crops, management practices and chemical amendments.

Based on high seed yield and stable performance of NCP-1 in different saline environment, it may be concluded that by promoting the cultivation of this genotype in saline areas, such as studied here, the yield of cowpea can be enhanced and ultimately it will be helpful to improve the economic position of the growers of those areas.

REFERENCES

Akhtar, J., Gorham, J. and Qureshi, R. H., (1994). Combined effect of salinity and hypoxia in wheat (*Triticum aesitivum L.*) and wheat-*Thinopyrum amphiploids*. Plant and Soil. **166**, 47-54.

Akhtar, J., Gorham, J., Qureshi, R. H. and Aslam, M., (1998). Dose tolerance of wheat to salinity and hypoxia come late with root dehydrogenize activities or parenchyma formation. Plant and Soil, **201**, 275-284.

Ali, Y., Aslam, Z., Sarwar, G. and Hussain, F., (2005). Genotype and environmental interaction in advanced lines of wheat under salt-affected soils environment of Punjab. Int. J. Environ. Sci. Technol., **2** (3), 223-228.

Anonymous, (2004). Agricultural Statistics of Pakistan. Government of Pakistan, Ministry of Food, Agriculture and Live Stock, Economic Wing, Islamabad. 83-84.

Ashraf, M. and Ahmad, S., (2000). Influence of sodium chloride on ion accumulation, yield components and fiber characteristics in salt tolerant and salt sensitive lines of cotton (*Gossypium hirsutum L.*) Field Crops Res., **66**, 115-127.

Baker, R. J., (1988). Test for crossover genotype – environmental interaction. Can.J.Plant Sci.,**68**, 405-410.

Bashir, M. and Hampton, R. O., (1996a). Identification of cowpea (*Vigna unguiculata*-L Walp) cultivars and lines immune to variants of black eye cowpea mosaic potyrus. Plant Pathol. **454**, 984-989.

Bashir, M. and Hampton, R. O., (1996b). Sources of genetic resistance in cowpea (*Vigna unguiculata*-L Walp) to cowpea aphid born mosaic potyvirus. Europ. Plant Pathol., **102**, 411-4119.

Bashir, M., Ahmad, Z. and Iqbal, T., (1999). Detection and identification of two seed- born potyviruses from imported seeds of cowpea (*Vigna unguiculata* L Walp) from Nigeria. In: Proceeding of 2nd National Conference of Pl. Pathol., sept. 27-29, Uni. Agri., Faisalabad, Pakistan, .41-46.

Eberhart, S. and Russel, W. A. (1966). Stability parameters for comparing varieties. Crop Sci. **6**, 36-40.

Finlay, W. and Wilkinson, G. N., (1963). The analysis of adaptation in a plant breeding programme. Aust. J. Agric. Res., **14**, 742-754.

Glenn., E., Pfister, R., Brown, J. J., Thompson, T. L. and Leary, J. W. O., (1996). Na and K accumulation and salt tolerance of *Atriplex canescens* (Chenopodiaceae) genotypes. Am. J. Bot., **83**, 997-1005.

Hampton R.O., (1983). Seed-born viruses in cop germplasm resources: disease dissemination risks and germplasm reclamation technology. Seed Sci. Technol., **11**, 536-546.

Latif Z. H., Ahmad, R. and Haq, M. I., (1999). Effect of seed treatment with neem cake, neem oil and Latex of Aak on the germination of cowpea and its vulnerability, root-knot nematode *Melodogyne incognita*. Pak. J. phytopath., **11**, 52-53.

Matus, A., Slinkard, A. E. and Kessel, C. V., (1997). Genotype x environment interaction for carbon isotope discrimination in spring wheat. Crop Sci. **37**, 97-102. Ph. D. dissertation, University of Hawaii, HI, USA.

Qadir, M. and Shams, M. (1997). Some agronomic and physiological aspects of salt tolerance in cotton (*Gossypium hirsutum L.*) J. Agron. Crop Sci., **179**, 101-106.

Rajput, M.A.,Sawar, G. and Tahir, K. H., (1986). Stability for grain yield in mungbean mutants. Bangladesh J. Nuclear Agri., **2**, 58-59.

Rehman, S. P., Harris, J. C. and Bourne, W. E., (1998). The effect of sodium chloride on the Ca^{++}, K^{+} and Na^{+} concentration of the seed coat and embryo of

Acaciatortilis and *A. cortacea.* Ann. Appl. Biol. **133**, 269-279.

Saqib M., Qurshi, R. H., Akhtar, J., Nawaz, S. and Aslam, M., (1999). Effect of salinity and hypoxia on growth and ionic compositions of different genotypes of wheat. Pak. J. Soil Sci., **17**, 1-8.

Sarwar, G., Sadiq, M. S., Saleem, M. and Abbas, G. (2003). Genotype x environment interaction in newly developed lentil germplasm under cotton based cropping system. Proc. Seminar "Sustainable utilization of plant genetic resources for agricultural production" 17-19 Dec.2002, NARC, Islamanad. 219-226.

Steel, R. G. D. and Torrie, J. H., (1980). Principles and Procedures of Statistics. Mc Graw Hill Book Company, Inc. New York.