Indian J. Genet., **56** (1): 69–78 (1996)

GENOTYPE X ENVIRONMENT INTERACTION FOR SEED YIELD IN CHICKPEA

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(Received: July 8, 1991; accepted: July 3, 1995)

ABSTRACT

Multilocational trials of 16 genotypes of desi and kabuli chickpea (*Cicer arietinum* L.) were conducted in a number of countries in three seasons at 17 (1981–82), 31 (1982–83), and 22 (1983–84) locations between 10°–52° latitudes. Combined analysis of variance for seed yield was done to study the genotype x environment interactions and stability of genotypes. Mean squares for locations, genotypes and genotype x location interactions were significant. Locations and genotype x location interaction variances were much higher than those for genotypes. Genotypes exhibited relatively more interaction with winter-sown locations than with spring-sown locations. Desi types showed more variation than the kabuli types. The mean squares due to desi and kabuli type interactions were higher than those for either desi or for kabuli types in two of the three years. Yield performance of the Indian kabuli cultivar L 550 was comparable with the best desi cultivar K 850. Seed size did not appear to influence yield performance and stability. Annigeri, Pant G 114, ICCC 8, L 550 and ILC 482 had relatively high yield with good stability. Implications of these observations in breeding for seed yield and wide adaptation are discussed.

Key words: *Cicer arietinum* L., genotype x environment interaction, stability analysis.

The genotype x environment (G x E) interactions encountered in multilocational trials is a challenge to plant breeders and can hinder progress in breeding widely adapted cultivars. Selection for yield is based on the phenotype which is influenced considerably by G x E interaction. Relatively little information is available on the performance and stability of chickpea (*Cicer arietinum* L.) genotypes across widely different environments [1]. Limited studies on phenotypic stability with local cultivars of this crop in India indicated that G x E component of variability for seed yield was significant and that most interactions were linear

[2–5]. However, Mehra and Ramanujam [4] also reported substantial nonlinear component. Mehra et al. [6] observed relatively wide adaptability in newly released cultivars in India. Chandra et al. [7] found that G x L (location) interaction was more important than G x Y (year) interaction. Ramanujam et al. [8] obtained lower genotypic variance compared to G x L interaction variance for kabuli type than for desi type chickpea. Tomer et al. [9] found that varieties with large seed were more unstable than those with smaller seeds. The purpose of the present study was to evaluate seed yield performance and G x E interactions of 16 chickpea (both desi and kabuli type) genotypes drawn from a number of chickpea growing countries.

MATERIALS AND METHODS

Sixteen genotypes of chickpea; 7 desi and 9 kabuli, representing various geographical niches and with differences in their seed size, colour, plant height, maturity and their reaction to fusarium wilt and ascochyta blight; comprised the materials for the present study (Table 1). The trials were laid out in a randomized complete block design with four replications. The plot size was 4 rows 4 m long spaced 30 cm apart. Plant to plant distance within a row was 10 cm. However, some cooperators used local practices with regard to sowing procedure, fertilization, moisture conservation and plant protection. Trials were conducted in diverse agroclimatic conditions in winter- and spring-planting zones. The latitudes of the experimental locations varied from 10° to 52° and altitudes from mean sea level to 1340 m.

Replication-wise seed yield data on plot basis for 17, 31 and 22 locations were received for 1981–82, 1982–83 and 1983–84 seasons, respectively. These locations included 17 from India; 4 each from USA and Pakistan; 2 each from Italy, Spain, Syria and Sudan; and one each from Algeria, Bangladesh, Brazil, Bulgeria, Canada, Costa Rica, Egypt, Iran, Iraq, Lebanon, Mexico, Nepal, Saudi Arabia, Turkey and Thailand. Four locations were common for all the three years, eight for the first two (1981–82 and 1982–83) for 13 for the last two years (1982–83 and 1983–84). Genotypes were assumed as fixed, and locations and years as random in the combined analysis of variance (ANOVA). Expectations of mean squares and F test for this model were employed as suggested by McIntosh [10]. Since error variances were heterogeneous when compared over locations (Bartlett's test for homogeneity), adjusted degrees of freedom were used to compare table values [11]. Stability analyses for seed yield following Eberhart and Russel [12] were performed for locations within each of the three years and for all 70 environments together.

RESULTS AND DISCUSSION

The ANOVA for individual years indicated a large influence of locations on chickpea performance (Table 2). This was expected because the locations were diverse for their latitudes, altitudes, planting seasons, soil types, fertility and rainfall. As chickpea is grown

Table 1. Origin, characteristics and parentage of 16 genotypes of chickpea

Genotype	Seed type	Seed colour	Seed maturity	Plant habit	Seed size	Disease reaction: Fusarium wilt	Disease reaction: Ascochyta blight	Origin	Pedigree
Harigantas	Desi	Black	Very short	SP	Small	S	S	Niphad, India	Local collection
Annigeri	Desi	Brown	Short	SS	Medium	R	S	Annigeri, India	Local collection
ICCC 4	Desi	Brown	Medium	SS	Small	T	S	ICRISAT, India	H 208 x T 3
ICCC 8	Desi	Brown	Medium	SS	Medium	T	S	ICRISAT, India	K 850 x F 378
K 850	Desi	Brown	Medium	S.Er	Large	T	S	Kanpur, India	Banda local x Etah bold
G 130	Desi	Brown	Long	SS	Small	T	S	Ludhiana, India	No. 708 x C 235
Pant G-114	Desi	Brown	Long	SS	Small	T	T/S	Pantnagar, India	G 130 x 154
L 550	Kabuli	Beige	Medium	SS	Medium	S	S	Ludhiana, India	C 104 x NP 12
Cyprus Local	Kabuli	Beige	Medium	S.Er	Large	S	S	Cyprus	Local collection
Giza	Kabuli	Beige	Medium	S.Er	Small	S	S	Giza, Egypt	Local collection
ILC 482	Kabuli	Beige	Medium	S.Er	Large	S	T	Adapazari, Turkey	Local collection
Iranian Local	Kabuli	Beige	Medium	S.Er	Medium	S	S	Iran	Local collection
Jordanian Local	Kabuli	Beige	Long	S.Er	Medium	S	S	Jordan	Local selection
Rabat	Kabuli	Beige	Long	S.Er	Medium	S	S	Morocco	Local selection
Syrian Local	Kabuli	Beige	Medium	S.Er	Medium	S	S	Syria	Local selection
Turkish Local	Kabuli	Beige	Medium	S.Er	Large	S	S	Turkey	Local selection

SP—spreading; SS—semispreading; S.Er.—semierect; S—susceptible; R—resistant; T—tolerant.

in winter or spring seasons, location effects were partitioned accordingly. Mean squares due to winter locations were much larger than those for spring locations. Interactions between spring and winter main effects were significant, but were of generally low magnitude.

Mean squares due to desi and kabuli types and their interactions were significant (except their interaction in 1981–82). In two of the three years interaction mean squares between desi and kabuli types were of much higher magnitude than for either desi or kabuli main effects. Between the two types, desi types were two to three times more variable than the kabuli types. This may in part be because of the large differences in the yields of Harigantas and other desi genotypes. Mean squares for genotype x location interactions were highly significant for each of the three years and for the pooled analysis over 70 environments in three years. Further partitioning showed that winter locations contributed much more towards variable performance of desi and kabuli types than did spring locations. This was further confirmed by the mean data and relatively higher magnitude of mean squares due to winter x desi vs. kabuli as compared to spring x desi vs. kabuli interactions (Table 2). The importance of winter locations in discriminating among the genotypes for their performance is apparent from these data.

Table 2. ANOVA (mean squares) of 16 International Chickpea Adaptation Trial genotypes for seed yield over locations from 1981/82 to 1983/84

Source	1981–82		1982–83		1983–84	
	d.f.	MS x 10^5	d.f.	MS x 10^5	d.f.	MS x 10^5
Locations:						
Spring	7	166.09**	9	183.80**	2	280.70**
Spring vs. winter	1	26.37*	1	17.99	1	391.50**
Winter	8	327.07**	20	337.80**	17	321.00**
Replications within location	51	3.92	93	33.05	66	4.17
Genotypes:						
Desi	6	25.31**	6	45.17**	6	79.51**
Desi vs. kabuli	1	0.81	1	158.90**	1	235.20**
Kabuli	8	15.59**	8	12.23**	8	24.47**
Genotypes x locations:						
Winter x Desi	48	7.55**	120	5.25**	108	6.92**
Spring x Desi	42	1.64**	54	2.44**	12	1.13
Winter x Kabuli	64	5.00**	160	3.49**	144	4.11**
Spring x Kabuli	56	4.58**	72	1.83	16	0.94
Winter x Desi vs. Kabuli	8	30.75**	20	18.74**	18	25.48**
Spring x Desi vs. Kabuli	7	21.03**	9	12.78**	2	0.13
Winter vs. Spring x Desi	6	2.28**	6	11.42**	6	5.77**
Winter vs. Spring x Kabuli	8	6.34**	8	16.32**	8	1.20
Winter vs. Spring x Desi vs. Kabuli	1	13.47**	1	232.60**	1	67.37**
Pooled error	749	0.82	1391	1.63	963	1.38
Adjusted error d.f.	389		763		505	

*,**Significant at 0.5 and 0.01 levels, respectively.

Combined analysis over years and locations expectedly showed a relatively small influence of years compared to either locations or years x locations interactions (Table 3). This suggests that for breeding for wider adaptability, the performance of lines should be measured over as many locations as possible.

Table 3. Mean squares for seed yield attributed to various factors for 16 International Chickpea Adaptation Trial genotypes grown at a number of locations, combined for two and three years

Source	1981–82 + 1982–83		1982–83 + 1983–84		1981–82 to 1983–84	
	d.f.	MS x 10^5	d.f.	MS x 10^5	d.f.	MS x 10^5
Years (Y)	1	262.06	1	0.01	2	110.41
Locations (L)	7	493.15	12	50.74*	3	970.85**
Y x L	7	152.07	12	18.30	6	84.72
Replications/Y x L	48	2.35	78(2)	0.39	36	2.19
Genotypes (G)	15	11.16	15	4.78**	15	21.13**
G x Y	15	2.94	15	0.28	30	2.07
G x L	105	8.98**	180	0.69**	45	8.43**
G x Y x L	105	2.73**	180	0.31**	90	2.63**
Error	720(6)	1.02	1170(58)	0.10	540	0.75

*,**Significant at 0.5 and 0.01 levels, respectively.

Figures in parentheses indicate the number of missing (estimated) values.

Partitioning of variances into components indicated overwhelming effect of locations on chickpea performance (Table 4). Next in importance were G x L variances. Genotypes were the least important. These findings call for widening the genetic base used in breeding programmes.

The desi types (except Harigantas), in general, produced higher seed yields than kabuli types. The general hardiness of desi types may be the reason for their better performance [13]. There are differences in their seed types, seed coat thickness, and some plant characteristics which appear to confer on desi types better tolerance to adverse conditions of drought and high temperature. However, the performance of L 550, an Indian kabuli, was comparable to that of the highest yielding desi, K 850. The latter had the largest seed size among desis. The seed yield of small-seeded kabuli, Giza was lower than large-seeded kabulis. Its seed size was even smaller than that of L 550. Thus our findings do not support the views of Tomer et al. [9] that desi types are hardier than the kabulis and that large-seeded genotypes are lower yielding than small-seeded genotypes. It should, therefore, be possible to breed kabulis and large-seeded desi types with high seed yield and stable performance.

Table 4. Estimates of variance components for seed yield for International Chickpea Adaptation Trial from analysis of variance over 1, 2 and 3 years

Variance component	Variances over years, x10^4					
	1981–82	1982–83	1981–82	1981–82 + 1982–83	1982–83 + 1983–84	1981–82 to 983–84
σ^2l	37.8	38.7	49.4	426.35	40.55	738.44
σ^2g	1.8	2.4	6.2	1.23	1.59	11.05
σ^2gl	13.4	9.1	12.0	31.25	1.90	19.33

l—locations, and g—genotypes.

Plant breeders generally agree on the importance of high seed yield and stability for developing varieties. In the present analysis, S^2_{di} was estimated but as the usefulness of the parameter has been questioned [14] we did not use it. In defining a stable variety, high yielding potential should also be taken into consideration though it is not an indicator of stability. The present investigation showed that some genotypes with high mean seed yield was associated with below average stability ($b > 1.0$) and vice versa (Table 5). Such association between mean performance and stability is not a desirable feature, because one would like to have genotypes which are capable of giving a high mean performance at a high level of phenotypic stability.

Considering the regression coefficients (Table 5) there was no indication that one (desi) or the other (kabuli) group had higher stability. ILC 482, Jordanian Local, Iranian Local and Rabat were as stable as desi types, ICCC 8, Pant G 114 and Annigeri. However, Jordanian Local, Iranian Local, and Rabat (all kabulis) showed consistently low yields, whereas L 550 and the two desis (Annigeri and Pant G 114), in general produced high seed yields. This indicated that the genotypes from India were more adaptable than those from other countries. However, such a conclusion may be inherent in the study as there were relatively more locations from India compared to other regions. This subject was considered in greater detail in another paper [1]. Regression coefficients were also computed in each of the three years for winter and spring locations, separately for the two groups of cultivars—desi and kabuli. There appeared to be no large difference for the different assessments of stability of these cultivars.

Overwhelming effect of locations on genotypic performance along with large G x L interaction suggests that there is a strong local adaptation in chickpea and varieties bred in one region may not do well in other regions. Similar conclusions were drawn by other workers [15, 16]. The effects of years on genotypic performance were nonsignificant over three years time span of the experiment. High correlations obtained for genotypic

Table 5. Mean seed yields, regression coefficients and deviation mean squares for International Chickpea Adaptation Trial genotypes grown from 1981–82 to 1983–84

Genotype	1981–82 (17 loc.)			1982–83 (31 loc.)			1983–84 (22 loc.)			1981–82 to 1983–84 (77 loc.)		
	$\overline{X}$	bi	S^2_{di} ($\times 10^5$)	$\overline{X}$	bi	S^2_{di} ($\times 10^5$)	$\overline{X}$	bi	S^2_{di} ($\times 10^5$)	$\overline{X}$	bi	S^2_{di} ($\times 10^5$)
Harigantas	669	0.32*	1.4	990	0.79*	1.5	822	0.53*	2.4	873	0.55*	1.9
Annigeri	1184	1.10	1.4	1464	1.23*	0.7	1576	1.10	0.9	1462	1.10	0.9
ICCC 4	1207	1.02	0.9	1437	1.11	0.8	1657	1.29*	1.3	1510	1.27*	1.4
ICCC 8	1071	0.89	0.4	1462	1.08	0.5	1540	1.23*	0.5	1435	1.13	0.5
K 850	1177	1.18	0.7	1585	1.12	0.4	1664	1.32*	0.5	1560	1.25*	0.5
G 130	995	0.80	1.1	1411	1.04	1.5	1505	1.08	1.7	1397	1.16*	2.0
Pant G-114	1064	0.70*	1.13	1473	0.86	1.6	1528	1.09	1.5	1454	1.12	2.6
Mean desi	1052.4			1403.1			1470.3			1384.4		
L 550	1261	1.18	0.5	1428	1.03	0.9	1562	1.11	0.3	1481	1.17*	0.8
Cyprus Local	876	1.19	1.3	1104	0.90	0.8	1137	0.82	0.9	1070	0.81*	1.3
Giza	949	0.63*	0.4	1137	0.98	0.4	1057	0.83	0.2	1083	0.78*	0.5
ILC 482	1277	1.35*	2.0	1266	1.08	0.6	1269	1.08	0.7	1297	1.05	1.1
Iranian Local	911	1.09	2.2	1202	0.95	1.2	1179	0.93	1.0	1144	0.91	1.4
Jordanian Local	979	1.01	0.5	1294	0.97	0.5	1073	0.93	1.0	1185	0.98	0.7
Rabat	1117	1.25	0.6	1425	0.98	- 0.1	1366	0.99	0.6	1291	1.06	0.3
Syrian Local	932	1.13	1.2	1171	1.02	0.8	1091	0.80	1.0	1098	0.83*	1.4
Turkish Local	1052	1.17	1.2	1195	0.88	0.8	1169	0.90	1.2	1167	0.83*	1.3
Mean kabuli	1039.3			1226.9			1211.4			1201.8		
Overall mean	1045.0			1304.0			1324.7			1281.7		
SE	89.3	0.15		63.3	0.10		79.0	0.11		47.4	0.11	
r between $\overline{X}$ & bi	0.64**			0.67**			0.94**			0.97**		

*,**Significant at 0.05 and 0.01 levels, respectively.

performance across years in this study support the view that testing of genotypes over years may not be useful. Instead multilocational testing would be helpful for selecting varieties with wider adaptation [1]. As genotypic variances were of low magnitude (in this study) even with cultivars from different regions, widening genetic variability used in breeding programmes is necessary.

The high mean seed yield and relatively wider adaptability of Annigeri, Pant G-114 and ICCC 8 in desi types and L 550 and ILC 482 in kabuli types indicated that these genotypes are good cultivars as such and may also be useful as parents in hybridization programmes. If L 550 is improved for its seed size and resistance to Fusarium wilt and Ascochyta blight, it may perform well and become acceptable in West Asia also, where the resistance to the latter disease and seed size are important.

Superior performance of genotypes from India may reflect breeding advantage because the varieties from North Africa and West Asia were only landraces. However, superior performance of the Indian varieties even in spring-sown locations (West Asia, USA, Canada) may be due to their favourable response to long-day conditions [17].

This study supported the earlier reports of occurrence of a large G x E interaction in chickpea [2–5]. It also showed that genotypic variation was only a fraction of the variance attributed to locations and G x L. Therefore, these results suggest a need for diversification of breeding and testing programmes to suit the immediate requirements of various regions. Further studies are required to demarcate zones where particular varieties could be grown. However, breeding efforts to adjust length of growing duration and incorporate resistances to major stress factors should help widen adaptation of new varieties. A beginning has been made at ICRISAT [18]. ICCV 10 released as Bharati in Central and Peninsular India and as Barichhola 2 in Bangladesh, has shown relatively wide adaptability. It should, therefore, be possible to breed such varieties of chickpea if testing of the breeding material is done in any diverse locations.

ACKNOWLEDGEMENTS

We are grateful to the cooperators in various countries who conducted these trials and returned the data. Dr. J. B. Smithson was involved in the initiation of this study. We acknowledge the help of Dr. D. Neeley and Mr. Venkat in interpretations of the trial data.

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