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Effects of selection criteria on yield stability in chickpea (*Cicer arietinum* L.)

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Summary. Selection in the F_3 generation for seed yield, fruiting branches/plant, effective pods/plant, and seed index (100-seed weight) was carried out in two chickpea crosses. Sixty F_5 lines (15 lines/selection criterion) along with check variety were evaluated for seed yield in three distinct environments. The effects of selection criteria on yield stability was examined using linear regression approach and genotype-grouping technique. There were no differences between selection criteria for linear yield responses of F_5 lines to different environments. Within all four selection criteria the lines showed similar linear responses. The non-linear component was relatively higher for lines selected for effective pods and seed index than lines selected for yield and fruiting branches. On the basis of mean yield and coefficient of variation across environments, the seed index was the least effective selection criterion for developing high yielding and stable lines. When the results of stability parameters and genotype-grouping technique were considered together, selection for yield and fruiting branches was highly effective for isolating stable and high yielding lines.

Key words: Chickpea – Early generation selection – G×E interaction – Stability – Yield components

Introduction

In spite of the fact that chickpea is the major winter food legume of India, its productivity is very low and has been fluctuating around 600 kg/ha. Consequently, the basic rationale for genetic improvement of chickpea is the development of cultivars with high and stable yield performance across environments.

Recent studies on early generation selection criteria based on seed yield and its components showed that the indirect selection via fruiting branches was effective for developing high yielding lines (Naidu et al. 1986; Dahiya et al. 1986). However, there is a need to delineate the yield responses of selected lines to environmental variation and extent of G×E interaction as a prelude for successful future breeding programs. It is also possible that early generation selection history may have some effect on yield stability in later generations.

Therefore, the present study was conducted in chickpea to investigate the magnitude of G×E interactions of selected lines, and to determine the effects of selection for yield and its components in early generations on yield stability.

Materials and methods

Two crossees between the *desi* chickpea cultivars (K468 and C235) as female parents and *kabuli* cultivar (L144) as a male parent were used in this study. In the F_2 generation of each cross, 4,500 plants were space planted (50×20 cm) in winter of 1981. At maturity 150 plants were harvested at random in each cross and planted as the F_3 lines in single-row plots with three replicates, the rows being 4 m long at 45 cm between rows and 20 cm between plants. The parent, C235, was planted in every 11th plot to serve as a control. In order to minimize the error variance due to soil heterogeneity or other microenvironmental factors while making selection in the F_3 generation, the performance of the F_3 lines as a per cent increase over adjacent control was computed for seed yield, fruiting branches/plant, effective pods/plant, and seed index (100-seed weight). Fifteen F_3 lines from both crosses with the highest increase over adjacent control for each of these four characters were selected. No progeny was selected for more than one character. The lines selected for seed yield were designated as Y lines, where the lines selected on the basis of fruiting branches, effective pods and seed index criteria were referred to as B lines, P lines and S lines, respectively. The F_4 line was obtained by bulking an equal number of seeds from 30 plants of the selected F_3 line. In F_4 the lines were grown in three replicate, randomized block design in one environment. At maturity, 30 random plants over three replicates for each F_4 line were bulk harvested to constitute an F_5 line.

Eventually sixty F_5 lines and C235 as a check variety were tested in rainfed and irrigated environments at Haryana Agricultural University, Hisar, and in a rainfed environment at Regional Research Station, Bawal. The material was planted in randomized complete block design with three replicates in all three environments. A plot consisted of two rows each, 4 m long at 45 cm between rows and 20 cm between plants within rows. Each plot was harvested in its entirety, and seed yield/plot was measured.

Table 1. Stability analysis for seed yield of F_5 lines selected for yield and its components

Source	d.f.	Mean square
Total	548	
Entries	60	16,725**
Criteria	3	17,264*
Within criteria	56	16,993**
Lines vs check	1	99
Entries vs Env.	120	11,260**
Lines × Env.	118	11,396**
Lines vs check × Env.	2	3,243
Env. (linear)	1	8,344,083**
Entries × Env. (linear)	60	11,484
Lines × Env. (linear)	59	11,658
Criteria × Env. (linear)	3	19,060
Within criteria × Env. (linear)	56	11,261
Y lines × Env. (linear)	14	13,224
B lines × Env. (linear)	14	8,182
P lines × Env. (linear)	14	11,545
S lines × Env. (linear)	14	12,094
Lines vs check × Env. (linear)	1	1,210
Deviations	61	10,429**
Lines	60	10,516**
Y lines	15	10,025*
B lines	15	6,402
P lines	15	13,246**
S lines	15	12,392**
Check	1	5,209
Pooled error (avg.)	360	5,675

* Significant at $P=0.05$; ** Significant at $P=0.01$

A linear regression analysis was performed on combined data over environments according to Eberhart and Russell (1966). A mixed model, treating lines as fixed and environments as random, was adopted because the selected lines were tested in three distinct environmental conditions. Genotype-grouping technique as proposed by Francis and Kannenberg (1978) was used for classifying the lines into four groups in terms of their relative yield and variation.

Results

Combined analysis of variance indicated significant variation due to environments, lines, and lines × environments interaction. Mean seed yield of 60 lines and check variety was 893 g at Hisar in irrigated environment, 424 g in rainfed environment, and 460 g at Bawal in rainfed environment. The variation in mean seed yield of lines (Table 1) was partitioned into variation between selection criteria and between lines within selection criteria. Both of these mean squares were significant when tested against the pooled error mean square. Apparently, there were wide differences in mean seed yield of lines selected for yield and yield components. There was also a considerable range of variation in the performance of lines within selection criteria.

A significant lines × environments interaction indicated that the lines did not perform consistently across environments. The lines × environment (linear) mean square was not significantly greater than the deviation mean square (Table 1). Thus, most lines × environments interaction was attributable to non-linear component. As indicated by non-significant Criteria × Env. (linear), there were no differences between selection criteria for linear responses of F_5 lines to varying environmental conditions. Similar linear responses were also observed between the lines within selection criteria. The check variety showed linear response similar to those of lines [Lines vs check × Env. (linear)]. Deviation mean squares for Y lines, P lines and S lines were significant. No significant deviations from regression were found for B lines and check variety. Clearly, the results showed the importance of

Table 2. Range and mean values (g/plot) for seed yield of F_5 lines developed by four selection criteria

Selection criterion based on	Hisar (irrigated)		Hisar (rainfed)		Bawal (rainfed)		Combined	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Yield	931	760–1,147	446	240–670	469	337–512	616	452–746
Branches	937	733–1,093	435	220–603	432	317–577	601	423–728
Pods	857	690–1,027	419	200–710	454	265–623	577	454–670
Seed index	835	590–1,090	401	245–625	477	348–707	571	452–701
C.D. 0.05	62		62		41		32	

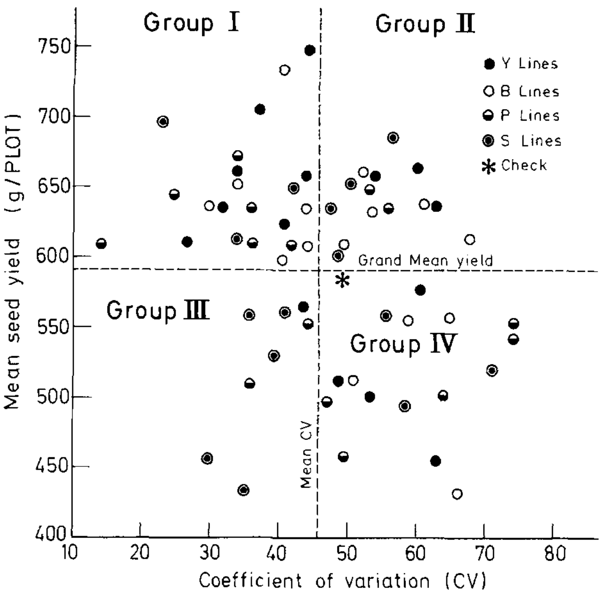

Fig. 1. Mean seed yield plotted against cv for 60 F_5 lines

Table 3. Stability parameters for lines of different selection criteria within each group

Group	Selection criterion based on	No. of lines	Mean seed yield (g/plot)	$\bar{b}$	S^2_{di}
I	Yield	7	670	1.00	10,271
	Branches	6	639	0.95	9,496
	Pods	6	631	0.77	5,593
	Seed index	3	654	0.71	11,658
II	Yield	3	649	1.38	955
	Branches	5	628	1.20	6,542
	Pods	2	641	1.23	58,384**
	Seed index	4	639	1.24	177,039**
III	Yield	1	634	0.88	115,549**
	Branches	0	–	–	–
	Pods	2	532	0.85	85,686**
	Seed index	5	507	0.71	3,430
IV	Yield	4	508	0.98	14,436*
	Branches	4	511	1.03	3,619
	Pods	5	505	1.25	159,254**
	Seed index	3	526	1.32	1,952

* Significant at $P=0.05$; ** Significant at $P=0.01$

non-linear component in comparing the stability of lines selected for yield, pods, and seed index.

In Table 2 the mean and range values within selection criteria for F_5 lines in three environments are summarized. The differences among the selection criteria were significant in irrigated environment at Hisar. In this environment the lines selected for seed yield and fruiting branches gave considerable higher yield than those selected for pods and seed index. In the other two environments there were no wide differences among selection criteria. The combined data also showed that selection for yield and branches yielded F_5 lines with high yield potential.

The mean yield and coefficient of variation (CV) across environments were computed for all the lines and check variety. Mean yields were plotted against CV values with grand mean yield and mean CV as base lines (Fig. 1) to assign the lines and check into four groups, namely, GI (high yield, small CV), GII (high yield, large CV), GIII (low yield, small CV), and GIV (low yield, large CV). The lines in GI could be considered the most desirable for high yield and relative stability. This group included 7Y lines, 6B lines, 6P lines, and 3S lines. These lines had considerably smaller CV than C235 (check) which was scattered in GIII. Though the mean yield of all the lines in GI was higher than C235, only two lines selected for yield and one line selected for branches produced seed yield significantly higher than C235. In GII there were 14 lines: 5B lines, 3Y lines, 2P lines, and 4S lines. These lines, being more responsive to environmental changes as indicated by large CV values, could be adopted for high yielding environments.

As a basis for comparing linear regression and mean CV methods, the regression coefficients and deviations from regression were computed on the basis of selection criterion within each group (Table 3). In GI, Y, and B lines had, on an average, almost unit regression and non-significant deviation mean square. Though P and S lines possessed non-significant deviation mean square, they had regression less than one. In GIII the lines within yield, pods, and seed index selection criteria had regression below unity. Deviation mean square was significant only for P lines.

Discussion

It is apparent that the major breeding challenge in chickpea is to achieve high and stable yield. The information on G×E interaction of advanced lines can be used to guide plant breeders in defining the specific direction of selection strategies in segregating generations for yield stability. In this study, the results indicated substantial lines×environments interaction. It was also quite evident that the major portion of lines ×environments interaction was contributed by non-linear component.

The predominance of non-linear component for yield in chickpea has also been reported by Jain et al. (1984). According to Joppa et al. (1971) and Baker (1984), significant deviations from regression may arise due to specific cultivar interaction. Therefore, the major contribution of non-linear component in the present study is the implication of it's effect on chickpea breeding strategy for selecting genotypes for local adaptation.

Since there were no differences between selection criteria for linear responses of lines to varying environmental conditions, it was not possible to conclude whether the selection for yield and yield components in early generations had effects on linear component for advanced lines. On examining the deviations from linearity, the non-linear interaction component for lines selected for pods and seed index was larger than that for lines selected for iruiting branches and yield. The regression coefficients and deviation from regression for individual lines were computed. Interestingly, though the linear component [lines × env. (linear)] of lines × environments was non-significant, several lines had significant regression coefficients.

Gautam and Jain (1977) reported that even though the linear component is non-significant, it is possible to identify promising genotypes with wide as well as specific adaptation.

Considering stability parameters in this study, two lines selected for yield, two lines selected for branches, and one line selected for pods appeared to be stable across the environments since their mean yield was higher than the general mean, bi = 1 and non-significant S^2_{di}. Four lines selected for yield, two lines selected for branches, one line selected for pods, and two lines selected for seed index combined high mean seed yield, $b_i > 1$ and non-significant deviations from regression. These lines may be desirable for high yielding environments. The number of lines suitable for low yielding environments was 2, 4, 4, and 2 selected for yield, branches, pods, and seed index, respectively. These lines were characterized by average yield, $b_i < 1$ and non-significant S^2_{di}.

The mean CV method is a simple, descriptive method to characterize genotypes for relative stability. The rationale for assigning the genotypes into four groups (GI, GII, GIII and GIV) in-terms of yield stability and variation was discussed by Francis and Kannenberg (1978). Only GI by virtue of high and consistent performance is considered stable. The results indicated that there were no wide differences between yield, branches, and pods selection criteria for number of lines scattered in GI. However, selection for seed index gave the lowest number of stable lines. When regression coefficient and deviation from regression were considered, the lines selected for yield and branches in GI were stable. For these lines the regression coefficient ($\bar{b}$) was unity and deviation from regression was non-significant.

In conclusion, selection in early generation for seed yield and yield components resulted in yield improvement in comparison to C235, a widely accepted cultivar of chickpea. There was evidence that the non-linear portion of G × E interaction seemed to be higher for lines selected for pods and seed index than lines selected for yield and fruiting branches. Hence, more emphasis may be given to seed yield and fruiting branches while making selections in early generations for developing stable lines with high seed yield.

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