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Early generation yield testing versus visual selection in chickpea (*Cicer arietinum* L.)

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Summary. Four F_3 populations of chickpea (*Cicer arietinum* L.) were simultaneously evaluated for yield in an F_3 yield trial and in single plant progeny rows. Ten high yielding, 10 low yielding and 10 randomly sampled lines, along with 10 lines visually selected for yield from the progeny rows, were retained for further evaluation. The lines from each of the four selection groups in each population were bulked and evaluated in a replicated yield trial at three locations and four environments. The bulk of visually selected lines was not superior in yield to the bulk of randomly sampled lines at all locations. The present results indicate that an early generation yield testing selection procedure is more efficient than visual selection for yield improvements in chickpea.

Key words: Chickpea – Selection methods – Visual selection – Early generation

Introduction

The primary concern of a plant breeder is to improve the genetic potential of cultivars for yield. Yield, however, is the least heritable of the traits under selection.

In recent years, plant breeders have been particularly concerned with the efficiency of breeding for yield. Several plant breeders have modified existing breeding methods in self-pollinated crops to permit a more effective selection for such quantitative characters as yield in the early generations of segregating populations (Bell 1963; Hurd 1969; Shebeski 1967). Selection for yield potential in the F_2 generation based on the yield of single plants (within crosses) has been ineffective in wheat (Shebeski 1967; McGinnis and Shebeski 1968; Briggs and Shebeski 1970; Knott 1972; DePauw and Shebeski 1973).

From studies conducted with barley, Fiuzat and Atkins (1953); Mckenzie and Lambert (1961) indicated reasonable success in selection for yield at the F_3 progeny level. Similar observations have been reported in soybeans (Raeber and Weber 1953) and wheat (Bjaanes 1951; Whitehouse 1953). Byth et al. (1969) also indicated that selection for yield on a plot basis in early generations of soybeans resulted in a maximum yield advance. Cooper (1976) showed that early generation yield testing in soybeans based on F_3 and F_4 families identified the most promising crosses and the most heterogeneous lines within crosses. In contrast, Leudders et al. (1973) found no significant differences in the mean yield of F_6 and F_7 lines selected in F_4 and F_5 using early generation yield testing, bulk and pedigree selection methods. However, they found that early generation yield testing in F_3, and bulk selection methods in soybean, retained more high yielding lines than did pedigree selection.

The pedigree system, the most common method used in grain legumes, has limitations: (1) selection within a single environment results in local adaptation; (2) the uniqueness of each year's climate, which results in changing selection pressure each year – important because yield is a character with low heritability. (3) the limitation on the amount of material and, particularly, genetic diversity, that can be advanced. For these reasons, the present study was conducted to compare the results of visual selection and early generation yield tests on yield and yield-related components in chickpea.

Material and methods

During 1978–79 four F_2 populations of chickpea, designated A to D, were grown as spaced plants. The pedigrees of the four populations were as follows: population A (H-208 × P-726-2); population B (H-355 × 850-3/27); population C (G-130 × 850-3/27); population D (F-61 × L-550). From each population 150 F_2 plants were visually selected and the F_3 seeds from each plant were planted in both a 2-row yield plot (50 seeds per row, 5 m long, 30 cm apart) and an F_3 progeny row (25 seeds/progeny row, 5 m long) on 28 October 1979 at

Hissar under normal cultural practices. The check cultivar H-208 was sown every fifth plot of the yield nursery and every tenth row of the progeny rows.

The yield of each plot was expressed initially as a percentage of the nearest check as a method of reducing the error variance (Knott 1972). Using this basis for yield determination, each population was tested for deviation from a normal distribution. Where deviations occurred, the F_3 analysis of variance was carried out on the basis of the transformation log plot minus log check.

The 10 lowest yielding, the 10 highest yielding, and a random sample of 10 lines from the F_3 yield trial were used to constitute three selection groups within each population, referred to hereafter as the high yielding bulk (HY), the low yielding bulk (LY), and the random bulk (RS), respectively. In addition, the 10 most promising F_3 progeny rows, on the basis of visual selection, were retained and a visual selection bulk (VS) was constituted from these progeny rows.

In 1980–81 the four F_4 bulks from each population were compared in a randomized block design, replicated 4 times in plots of 10 rows spaced 30 cm apart and 5 m long at three locations and in four environments.

The data recorded were number of primary branches, pods per plant, and 100-seed weight on ten random plants from the centre of the plot. The seed yield was recorded on a net plot basis (8 rows, 4 m long).

Two way analysis of variance was used to evaluate treatment differences in terms of yield and yield components within populations and environments and subsequently over all the environments. By making use of the concept of contrast (Ostle 1966) the following comparisons were tested for each population: 1) yield of VS vs HY bulks; 2) combined yields of VS bulk and the HY bulk vs RS bulk, and 3) yied of LY bulks vs the combined yield of all other bulks. To evaluate the effects of selection on yield and its components in both individual and combined analysis, Duncan's multiple range test was used.

Results

Seed yield

Significant deviations from normality were observed in all four populations when seed yield was expressed as a percentage of the check. Analysis of variance based on the transformation (log plot minus log check) showed that the mean yield of both the 10 lowest and 10 highest yielding F_3 lines (percentage of the check) of populations B, C and D deviated significantly from the mean yield of the random sample (Table 1). In all four populations F_3 lines selected on the basis of visual selection (based mainly on pods/plant) yielded significantly more than the random sample of lines in all the four populations and were superior to the 10 lowest yielding lines in populations B, C and D. The 10 highest yielding lines were superior and significantly higher yielding than random and visually selected lines in all the four populations.

The analysis of selection group bulk yields at different locations revealed the population × location interactions to be significant. In population A, the VS and HY bulks were significantly superior in yield than either the RS or the LY bulks (Table 2) however, no significant differences in yield occurred between VS and HY bulks at Hissar (irrigated). At Hissar (rainfed) LY was significantly low yielding than all other bulks in populations A and C whereas in populations B and D, LY and VS bulks did not differ significantly. RS bulk was even superior to VS bulk in population D. The differences between RS and VS bulks were nonsignificant at Ambala. RS bulk was superior to LY bulk in all the four populations at Kaul, whereas LY and VS were at par in population B. HY bulk was significantly superior to the other bulks at all environments except to VS at Hissar (irrigated) as well as in combined analysis over all the environments, excepts population D. However, the combined analysis showed that there were no significant differences between LY, RS and VS bulks. In population B, the combined analysis of selection group bulk yields showed that LY bulk was a significantly low yielder than the other three bulks. VS bulk was not higher yielding than the RS bulk, whereas HY bulk was significantly different in yield from the other three selection group bulks. A trend similar to population B was observed in the yields of different

Table 1. Mean yields of F_3 lines selected for the comparison of pedigree vs. early generation yield testing

Selection group	Population A		Population B		Population C		Population C	
	Mean % check[b]	Mean (log)[c]	Mean % check	Mean (log)	Mean % check	Mean (log)	Mean % check	Mean (log)
LY bulk	26.11	−0.1327[a]	22.21	−0.1091[a]	43.18	−0.2455[a]	18.63	−0.0899[a]
RS bulk	5.84	−0.0355[a]	1.67	−0.0073[b]	16.67	−0.0792[b]	30.89	0.1331[b]
VS bulk	20.43	0.0790[b]	58.30	0.1994[c]	65.53	0.2189[c]	86.18	0.2699[c]
HY bulk	107.12	0.3160[c]	129.98	0.3617[d]	163.27	0.4204[d]	195.12	0.4700[d]

[a] Duncan's multiple range test at $P = 0.05$; values followed by same letter are not significantly different
[b] Plot yield minus check plot yield, expressed as a percentage of the nearest check plot
[c] Plot yield expressed as log plot minus log check plot yield in grams

Table 2. Comparison of the mean yields of F_4 bulks from pedigree and early generation yield tests within individual populations different locations and combined

Population	Selection group	Seed yield (kg/ha)				Combined
		Hissar (irrigated)	Hissar (rainfed)	Ambala	Kaul	
A	LY	237.5*	215.0[a]	950.0[a]	396.6[a]	449.8[a]
	RS	301.2[a]	275.0[b]	1,150.0[a]	483.3[b]	527.4[a]
	VS	382.5[b]	385.0[b]	1,216.7[a]	500.0[b]	621.4[b]
	HY	352.5[b]	465.0[c]	1,700.0[b]	590.0[c]	776.9[c]
B	LY	482.5[a]	200.0[a]	1,183.3[a]	433.3[a]	574.8[a]
	RS	577.5[b]	240.0[a]	1,600.0[b]	550.0[b]	741.9[b]
	VS	550.0[b]	250.0[a]	1,633.3[b]	450.0[a]	720.8[b]
	HY	615.0[b]	365.0[b]	1,733.3[b]	650.0[c]	840.8[c]
C	LY	315.0[a]	187.5[a]	1,150.0[a]	400.0[a]	513.1[a]
	RS	347.5[b]	270.0[b]	1,383.3[b]	516.7[b]	629.4[b]
	VS	505.0[c]	440.0[c]	1,433.3[b]	566.7[b]	736.2[b]
	HY	500.0[c]	385.0[c]	1,816.7[c]	700.0[c]	850.4[c]
D	LY	370.0[a]	335.0[a]	1,333.3[a]	266.7[a]	576.2[a]
	RS	430.0[a]	440.0[b]	1,750.0[b]	370.0[b]	747.5[b]
	VS	507.5[a]	345.0[a]	1,600.0[b]	616.6[c]	767.3[b]
	HY	485.0[a]	445.0[b]	1,833.3[c]	671.7[c]	858.7[b]
$S\bar{x}$		19.98	25.21	56.11	28.32	
CV (%)		28.30	17.35	13.77	18.43	

* Duncan's multiple range test at $P=0.05$; values followed by same letter are not significantly different

Table 3. Mean squares for single degree of freedom. Comparisons of early generation and pedigree of selection for yield between selection group bulks overall populations

Selection group	Location	Mean squares
VS bulk vs. HY bulk	Hissar (irrigated)	66.6
	Hissar (rainfed)	9,600.00**
	Ambala	601,666.7**
	Kaul	2,016.7*
RS bulk vs. VS bulk + HY bulk	Hissar (irrigated)	450.0
	Hissar (rainfed)	49,088.9
	Ambala	281,250.00
	Kaul	101,250.00
LY bulk vs. VS bulk + HY bulk + RS bulk	Hissar (irrigated)	260,100.0*
	Hissar (rainfed)	108,350.0*
	Ambala	1,531,406.2**
	Kaul	294,306.2**

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

selection groups of population C. In population D the mean of four environments indicated that the yields of the different selection group bulks except LY bulk did not significantly differ from one another (Table 3).

The yield differences among the four selection group bulks tested at Hissar (irrigated), Hissar (rainfed) and Kaul reflected more clearly the effect of F_3 selection procedure in populations A, C and D than did the results obtained at Ambala and in different populations. In populations B, C and D, both RS and VS F_4 bulks were significantly higher yielding than LY bulks (Table 4). The difference in yield between VS and HY bulks was significant in all the populations except in population D. In all the populations, the RS bulk was not significantly different in yield from VS bulk, although it tended to be lower in yield except in population B. The HY bulks were significantly higher yielding than the other bulks except in population D. The LY bulks across all populations produced the lowest yield at all locations.

The analysis of population-selection group effects at each location, based on a fixed effects factorial model, indicated that there were significant differences between the VS and HY bulks at three locations (Table 3). At all locations the RS bulk was lower-yielding than the VS and HY bulks combined but the differences were not significant. Similarly, the LY bulks across all populations produced the lowest yield at all locations.

Primary branches/plant

The analysis of individual populations at each location showed no significant differences in primary branches between selection groups. Similar results were obtained from a combined population analysis grown in dif-

Table 4. Seed yield component means for pedigree and early generation F_4 yield tests at different locations

Location	Selection group	Primary branches/plant	Pods/plant	Seeds/pod
Hissar (irrigated) (29°10′N, 75°46′E)	LY	1.9[a]	37.5[a]**	1.3[a]*
	RS	2.1[a]	43.2[a]	1.3[a]
	VS	2.3[a]	46.8[a]	1.4[a]
	HY	2.2[a]	44.6[a]	0.051[a]
	S. Em.	0.250	6.753	0.051
Hissar (rainfed) (29°10′N, 75°46′E)	LY	2.2[a]	70.2[a]	1.3[a]
	RS	2.4[a]	73.5[a]	1.4[a]
	VS	2.5[a]	78.4[a]	1.4[a]
	HY	2.7[a]	89.2[b]	1.4[a]
	S. Em.	0.165	7.506	0.058
Ambala (30°22′N, 76°47′E)	LY	4.9[a]	64.8[a]	1.5[a]
	RS	5.2[a]	64.9[a]	1.5[a]
	VS	6.2[a]	73.6[a]	1.5[a]
	HY	5.7[a]	91.6[a]	1.5[a]
	S. Em.	0.898	13.251	0.083
Kaul (29°51′N, 76°40′E)	LY	1.5[a]	34.5[a]	1.4[a]
	RS	1.8[a]	38.6[a]	1.5[a]
	VS	1.6[a]	41.5[a]	1.5[a]
	HY	2.6[a]	50.5[a]	1.7[b]
	S. Em.	0.398	7.808	0.127

* Duncan's multiple range at $P=0.05$; values followed by the same letter are not significantly different

ferent environments (Table 4). The environment at Ambala was the most favourable for this character and highest number of primary branches were recorded by the VS bulk.

Pods/plant

The comparison of selection effects on pods/plant in different populations at each location indicated that at Hissar (rainfed) and Ambala the pods/plant of the HY bulks were significantly higher than the bulks developed by the other three selection methods. Although there were no significant differences between VS, RS and LY bulks, the LY bulks produced fewer pods/plant. At Kaul and Hissar (irrigated) the selection bulks did not exhibit any differences.

Seeds/pod

Analysis of selection effect on seeds/pod showed no significant differences between selection groups in the individual populations at different locations except the HY bulk produced significantly more seeds/pod at Kaul (Table 4). Also, except for the HY bulk at Kaul, no significant differences in seeds/pod occurred in either of the combined population analysis at each location. The presence of non-significant differences can be attributed to the absence of any differences among parents for this character.

Discussion

A common method for evaluating visual vs plot yield selection procedures has been to compare the mean yield of plots selected visually with yields from plots selected on the basis of a yield trial (Briggs and Shebeski 1971). Townley-Smith et al. (1973) and Mundel (1972), working on wheat, found that visually selected lines in an F_3 yield trial resulted in an increased yield but the yield increment was small compared to selection on the basis of plot yield. However, the results of the present study differed from these earlier observations. Also, the present results did not agree with those of Leudders et al. (1973); Seitzer (1974) and Boerman and Cooper (1975) who did not find any difference in mean yield of lines derived from pedigree and early generation yield testing. As the combined analysis at each location and over locations indicated, the lines selected in F_3 yield trial were more efficient than visual selection in the identification of high yielding material.

The major disadvantage of yield testing F_3 lines is the limited number of progenies that can be tested. A second consideration is the importance of inter-plant competition within yield plots. This problem was studied by Allard and Adams (1966) in wheat and barley. They found that high-yielding lines of poor competitive ability suffered heavy reduction in productivity in mixtures. Similarly, Khalifa and Qualset (1975) concluded that bulks should not be used for fear of losing desirable semidwarfs. In the present study, rejection of lines solely on the basis of yield in the F_3 early generation yield trial may not reduce the number of desirable segregants in future generations because there is not that severe interplant competition in chickpea as between semidwarfs and talls in wheat. Also there were not many differences in plant types in the parents used in this study.

The results from combined locations in the present study showed that selection of the highest-yielding F_3, HY lines resulted in a significant increase over both random and visual selections for seed yield. The different seedling rates used in the F_3 progenies for yield (50 seeds/5 m row) compared with the visual selection (25 seeds/5 m row) could result in differential responses of plant progenies to varying interplant densities. Such a possible response was ignored, however, in that the evaluation of individual plants in the visual selection bulk necessitated the use of relatively low plant density per row. In contrast, yield evaluation within the F_3 progenies was based on standard planting rates that are being used consistently in the chickpea breeding programme. The F_3 yield trial selection method resulted in significant yield increases over both random and visual selections.

The results of the present study indicated that visual selection was not so successful in identifying high yielding lines of chickpea when compared to F_3 yield testing. Relative to selection based on F_3 yield tests, visual selection was not equally effective for all four populations constituting this study. Comparisons made between overall populations of selection groups clearly demonstrated that visual and random selections were equally effective in the identification of high yielding lines. Visual selection was found more effective than random selection in the identification of high yielding lines (Stuthman and Steidl 1976). In chickpea, lines of inferior performance can be more easily identified than lines of high performance. There is also an indication from the present study that among-populations, comparisons can be made by visual selection. The highest yielding population (D), identified by visual selection and by yield tests in F_3, was again the highest yielding in the F_4 generation.

The use of visual selection (pedigree method) in chickpea for the improvement of agronomic characteristics other than seed yield also appears equally as effective as selection on the basis of actual yield trials. In the present study, primary branches/plant, pods/plant and seed/pod were not significantly influenced (either in a positive or a negative direction) by visual selection. Although pods/plant was used as a criterion for selection of the best yielding lines in this study, which has been a general practice in the chickpea breeding program, as pods/plant is the most important component of seed yield. On the basis of the results of present investigation it was observed that since seed yield is the least heritable trait, therefore, early generation yield testing may be preferred to visual selection for the improvement of seed yield of chickpea because in segregating generations the visually selected superior plants may be more due to favourable environment rather than genotypic superiority. Thus, selection on the basis of yield per se in early generations is more desirable for improvement in yield.

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