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RESEARCH ARTICLE

EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA

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ABSTRACT

Five F_2 populations and their selected F_3 progenies of chickpea formed by crossing seven parents were studied in consecutive years. Ten F_2 plants from each population were selected for high as well as for low expression of pods per plant, seeds per plant, harvest index and seed yield per plant. A total of 226 selected F_3 progenies were evaluated in randomized block design with three replications in succeeding year. Selection for high level had maintained their higher expression for pods per plant, seeds per plant and seed yield. Effectiveness may be considered as moderately successful because of 40% of high yielding F_3 progenies were derived from F_2 plants selected for high pod number. Response of selection through pods per plant found effective for improvement of seed yield in all the crosses. No definite selection pattern was found for identification of superior yielding lines. However, some superior yielding F_3 lines were found to derive by high order selection for all the traits. Selecting for high pod number in early generation, a foremost consideration needs to be the influence of environment on the effectiveness of selection.

INTRODUCTION

Among the pulses, chickpea (*Cicer arietinum* L.) is the most important crop with high acceptability and wider use. It is cultivated mainly on marginal lands under rainfed condition in *Rabi* season (Shiyani *et al*., 2001). Two distinct market types' i. e. *desi* and *kabuli*, are recognized (Pundir *et al*., 1985). Restricted genetic variability available for agronomic characters is a major limitation of pulses improvement in general and chickpea in particular. In chickpea breeding programme, enhancement of genetic potential for seed yield is of paramount important objective. Grafius (1956) suggested that seed yield might be effectively increased by selecting for one or more yield components. Seed yield improvement by yield component selection should be superior to selection for yield *per se*, when the component traits have a high heritability than yield and when the genetic correlation between the two traits is high (Falconer, 1960). Rahman and Bahl (1986) reported that selection for seeds per pod and 100-seed weight is fruitful in F_3 generation of chickpea. Kumar and Bahl (1992) found indirect selection based on pod number and seed weight to be more effective than either direct selection for yield itself or indirect selection through seeds per pod or random selection. Dahiya *et al*. (1984) reported effectiveness of selection for high yielding over visual selection. While, Ravinder *et al*. (2006) found direct selection for seed yield as more effective method.

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The objectives for this study were (1) to study the effect of selection on estimates of mean, coefficient of variation and correlation (2) to assess relationship between the two successive generations and (3) to examine the effectiveness of selection based on yield components in terms of yield response.

MATERIALS AND METHODS

Plant material and experimental detail

The study was carried out for four years at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. The experiments were comprised of a crossing block, F_1, F_2 and F_3 populations of five crosses in chickpea. Eight parents were sown during *Rabi*-2007 in non replicated crossing block consisting of three rows for each parents of five metre length with between rows spacing of 60 cm and plant to plant distance of 20 cm to facilitate the hand emasculation and pollination. Five crosses *viz*., GJG 9905 X Vishal (Cross 1), GJG 9905 X CSJ 103 (Cross 2), GJG 0106 X Phule G 96006 (Cross 3), JCP 27 X IPC 2000-52 (Cross 4) and JCP 27 X CSJ 103 (Cross 5) were attempted. Among the parents, GJG 9905 and Vishal are early maturing with short flowering duration, CSJ 103 and JCP 27 are of late maturity with higher pod bearing capacity and higher seed weight, GJG 0106 possesses low harvest index, while Phule G 96006 has short plant stature and low seed weight and harvest index. IPC 2000-52 is intermediate in maturity and harvest index. All the five F_1s were hand sown in Rabi-2008 and allowed to self for advancement of generation.

F_2 studies

The parents and F_2 seeds were sown during *Rabi* - 2009 in a randomized block design with three replications. Five rows of each F_2 and single row of each parent were hand sown to each plot of four meters length, keeping row to row and plant to plant spacing of 45 cm and 10 cm, respectively. The measurements were taken at maturity on randomly selected five plants from each parent and 75 plants from each F_2 per replication. The high and low groups were generated for each cross by selecting the ten highest and the ten lowest F_2 plants per selection criterion. Four selection criteria were investigated which were based on seed yield per plant, pods per plant, seeds per plant and harvest index. Since several of the plants were selected for more than one character, only a total of 226 F_2 plants were selected for either high or low trait in all the crosses.

F_3 studies

The F_3 progenies of 226 selected F_2 plants were grown in single row plots of four meter length with spacing of 45 x 10 cm in randomized block design replicated thrice during *Rabi*-2010. The data in F_3 were collected on four characters. Number of pods and seeds were recorded on plant basis, whereas seed yield (g) and harvest index (%) were measured on plot basis.

Statistical Analysis

The average values of the characters were subjected to statistical analysis according to design used in the study. These data were also used to calculate mean $\left(\overline{X}\right)$ and coefficient of variability (CV) by using following formula.

$$\overline{X} = \frac{\sum X}{N}$$

Where, $\sum X$ is sum of measurement for a character and N is number of sample for a character. Variance (σ^2) was calculated as the sum of square of deviation from its mean and divided by the degree of freedom. Thus, it represent as follows.

$$\sigma^2 = \frac{\sum X^2 - \frac{\left(\sum X\right)^2}{N}}{N-1}$$

Where, $\sum$ is summation, X is individual sample value of a character and N is number of sample. Standard error (SE) for each mean was worked out according to following formula.

$$SE = \frac{\sqrt{\sigma^2}}{\sqrt{N}}$$

Coefficient of variation (CV) was calculated by using following formula.

$$CV\ (\%) = \frac{\sqrt{\sigma^2}}{\overline{X}} X 100$$

Simple correlation coefficient between the characters was worked out according to the procedure of Al-Jibouri *et al.* (1958). The data recorded on F_2 selected plants as well as on F_3 progenies for high and low groups were used for this purpose. Covariance for a pair of characters was computed in similar fashion as variance for individual character in the F_2 and F_3 generations. Formula used for calculating simple correlation coefficient is as under.

$$rxy = \frac{CO\hat{V}(xy)}{\sqrt{\hat{\sigma}^2 x . \hat{\sigma}^2 y}}$$

Where, *Rx y* is simple correlation coefficient between variables x and y, $CO\hat{V}$ (xy) is covariance between two variables x and y in F_3 population, $\hat{\sigma}^2 x$ is variance of x variable and $\hat{\sigma}^2 y$ is variance of y variable The test of significance for correlation value was done by calculating'‘t’ value using following formula.

$$t = \frac{r}{\sqrt{1-r^2}} X \sqrt{n-2}$$

Where, t is calculated value of ‘t’, r is correlation coefficient and n is number of observation. The calculated ‘t’ value was compared with table ‘t’ value at n-2 degrees of freedom to test the significance of correlation coefficient.

Heritability (h^2) and genetic advance (GA) based on relationship between two successive generations (Cahaner and Hillet, 1980) were computed as under.

$$Heritability(h^2) = \frac{\text{covariance between parent } (g_2) \text{ and progeny } (g_3)}{\text{Variance of progeny } (g_3)}$$

Where, g_2 is the initial generation and g_3 in the following generation. Genetic advance (GA) as percentage of mean was computed as per following formula.

$$GA as\ (\%)\ Mean = \frac{K \times \sqrt{\text{variance of progeny } (g_3)} \times h^2}{\overline{X}} X 100$$

Where, K is equal to 2.06 (selection intensity at 5%) and $\overline{X}$ is mean of F_3 progeny. Parent-offspring correlations were worked out according to Frey and Horner (1957).

$$b' = bxy\left(\frac{\hat{\sigma}x}{\hat{\sigma}y}\right) = rxy = \frac{CO\hat{V}(xy)}{\sqrt{\hat{\sigma}^2 x . \hat{\sigma}^2 y}}$$

b’ = byx= rxy = σ

b’ =ryx ± S.E. of ryx

Where, *cov (xy)* is co-variance between parents and progenies, *by x* is regression co-efficient of parents on progenies and *ryx* is correlation co-efficient between parents and progenies. Response to selection was assumed to be the difference between high F_3 progeny means and the low F_3 progeny means. Student 't' test was employed to judge the real difference between high and low F_3 progeny. Also, selection effectiveness was assessed by taking the 10 highest yielding F_3 lines of each cross and examining their corresponding F_2 selection group patterns.

RESULTS

Mean values and coefficient of variations

The data presented in Table 1shows that means of F_3 selected lines for high and low expression were higher than their respective F_2 means in all the crosses and characters. As F_2 and F_3 populations were studied in two succeeding years, higher mean expression of low selection group over F_2 means of respective character indicated that environmental conditions for the crop of F_3 populations would be more favourable. Coefficient of variation (CV) in F_3 lines for high and low group were not always higher or lower than their respective CV in F_2 generation, *i.e.*, mixed trend was observed. In Cross 1, F_3CV both of high and low group was lower than their respective F_2CV for pods per plant, seeds per plant and harvest index. In Cross 2, this estimate of both groups was higher for seeds per plant and seed yield, and lower for harvest index. Similarly, as compared to F_2CV, Cross 3 expressed F_3CV values higher of both high and low group for pods per plant, seeds per plant and seed yield, and lower for harvest index. In case of Cross 4, F_3CV values were lower for pods per plant and higher for seed yield. Higher F_3CV values in the Cross 5 were observed for seeds per plant, seed yield and harvest index. On the other hand, Cross 1 and 3 for seeds per plant, Cross 2 and 5 for pods per plant and Cross 4 for harvest index expressed either higher or lower magnitude of F_3CV over their respective F_2 CV. Thus, trend of increase or decease in CV values of F_3 over F_2 was not consistent.

Table 1. Mean and coefficient of variation (CV) in F_2 populations and F_3 selected lines for high and low group of yield and its components in five chickpea crosses

Character/ Crosses§	F_2 population		F_3 selected lines			
	Mean	CV%	Mean		CV%	
			High	Low	High	Low
Pods/plant						
Cross 1	22.83 ± 0.32	22.91	73.48 ± 1.90	70.29 ± 2.12	18.97	22.14
Cross 2	33.44 ± 0.41	20.23	88.67 ± 2.24	58.83 ± 2.38	18.62	29.72
Cross 3	37.18 ± 0.26	11.61	61.68 ± 3.10	58.29 ± 1.48	37.01	18.65
Cross 4	27.52 ± 0.36	21.90	75.98 ± 2.06	65.52 ± 1.24	19.90	13.87
Cross 5	29.69 ± 0.31	17.15	78.38 ± 1.57	50.16 ± 1.18	14.75	17.25
Seeds/plant						
Cross 1	26.70 ± 0.33	20.20	93.64 ± 2.42	87.93 ± 2.20	19.02	18.36
Cross 2	41.35 ± 0.42	16.73	112.46 ± 3.21	78.16 ± 2.33	21.02	21.90
Cross 3	49.42 ± 0.38	12.86	79.91 ± 2.17	78.16 ± 3.51	20.00	34.08
Cross 4	40.93 ± 0.37	14.81	109.17 ± 3.09	82.00 ± 1.33	20.79	11.94
Cross 5	40.24 ± 0.40	16.67	97.65 ± 2.45	63.44 ± 2.40	18.44	26.56
Seed yield (g)						
Cross 1	3.38 ± 0.05	26.51	120.10 ± 3.42	92.50 ± 3.35	20.92	26.60
Cross 2	5.69 ± 0.07	19.02	89.02 ± 2.66	88.41 ± 3.47	21.94	28.87
Cross 3	6.35 ± 0.05	13.31	121.35 ± 5.25	92.63 ± 2.21	31.82	17.58
Cross 4	4.95 ± 0.04	12.95	81.85 ± 1.95	79.91 ± 2.65	17.51	24.41
Cross 5	5.17 ± 0.07	21.70	104.20 ± 4.12	95.12 ± 3.30	29.05	25.48
Harvest index (%)						
Cross 1	24.52 ± 0.28	19.06	52.21 ± 0.71	57.85 ± 0.96	10.03	12.09
Cross 2	26.94 ± 0.40	24.81	46.37 ± 1.30	53.97 ± 1.02	20.64	13.92
Cross 3	30.64 ± 0.32	17.44	55.57 ± 1.14	64.74 ± 0.69	15.09	7.79
Cross 4	30.70 ± 0.27	14.70	48.69 ± 1.87	58.11 ± 0.99	28.23	12.58
Cross 5	35.29 ± 0.27	12.76	41.99 ± 0.95	40.94 ± 0.75	16.62	13.42

§ Cross 1 = GJG 9905 X Vishal,Cross 2 = GJG 9905 X CSJ 103,Cross 3 = GJG 0106 X Phule G 96006,Cross 4 = JCP 27 X IPC 2000-52 and Cross 5 = JCP 27 X CSJ 103

Correlation coefficients

Simple correlation coefficient estimated for possible pairs of four characters in F_2 and F_3 generations (ignoring high and low groups) of five crosses (Table 2) reveals that correlations of pods per plant with seeds per plant and seed yield were highly significant in F_2 and F_3 populations of all the crosses, except F_2 of Cross 4, the relationships found more stronger in F_3 over F_2. Such definite patterns of relationships were also observed between seeds per plant and seed yield. On the contrary, change in strength and direction of correlation in F3 over F2 generation was inconsistent for harvest index with other studied traits.

Table 2. Simple correlation coefficient(r) among four characters in F_2 and F_3 generation (ignoring high and low groups) in five chickpea crosses

Character combinations and crosses§	" r " value	
	F_2	F_3
Pods/plant with seeds/plant		
Cross 1	0.79**	0.86**
Cross 2	0.73**	0.87**
Cross 3	0.55**	0.87**
Cross 4	0.49**	0.79**
Cross 5	0.71**	0.84**
Pods/plant with seed yield		
Cross 1	0.73**	0.74**
Cross 2	0.64**	0.85**
Cross 3	0.54**	0.84**
Cross 4	-0.11	0.84**
Cross 5	0.68**	0.79**
Pods/plant with harvest index		
Cross 1	0.17*	0.35*
Cross 2	0.31**	-0.30
Cross 3	-0.31**	0.28
Cross 4	0.49**	-0.38*
Cross 5	-0.17*	0.11
Seeds/plant with seed yield		
Cross 1	0.68**	0.73**
Cross 2	0.50**	0.83**
Cross 3	0.69**	0.89**
Cross 4	0.60**	0.87**
Cross 5	0.70**	0.88**
Seeds/plant with harvest index		
Cross 1	-0.31**	-0.08
Cross 2	-0.45**	-0.31
Cross 3	-0.73**	-0.33*
Cross 4	-0.79**	-0.43**
Cross 5	-0.69**	-0.01
Seed yield with harvest index		
Cross 1	0.45**	0.05
Cross 2	0.53**	0.03
Cross 3	-0.04	-0.01
Cross 4	-0.03	0.35*
Cross 5	-0.01	0.56**

§ cross codes as per Table 1; *and** represent significant values at p=0.05 and p=0.01 probability levels, respectively

Response to selection for selected traits

The mean value of F_2 plants selected for high and low expression and the actual mean of high and low F_3 lines derived from them (Table 3) indicated that per cent differences between high and low group, relative to their respective high group (H-L/H x 100) in F_2 generation ranged from 30.52 to 87.70 % and in F_3 generation ranged from -19.35 to 36.00 %. Also, per cent differences in F_3 were found to be reduced compared to F_2 for the characters studied in all the crosses, except pods per plant and seeds per plant in Cross 5, though such estimates were found even negative for harvest index in F_3 of some crosses.

Table 3. Per cent mean differences between high and low groups of selected F_2 plants and their F_3 lines for four characters in five chickpea crosses

Cross§	Selected characters	Generations	Mean of selected F_2 plants or their F_3 lines: High	Low	$\frac{H-L}{H} \times 100$
Cross 1	Pods /plant	F_2	32.60	12.70	61.04
		F_3	73.48	70.29	04.34
	Seeds/plant	F_2	37.10	20.00	46.09
		F_3	93.64	87.93	06.10
	Seed yield (g)	F_2	12.22	2.06	83.14
		F_3	120.10	92.50	22.98
	Harvest index (%)	F_2	32.30	14.78	54.24
		F_3	52.21	57.85	-10.80
Cross 2	Pods /plant	F_2	51.50	29.90	41.94
		F_3	88.67	58.83	33.65
	Seeds/plant	F_2	65.70	39.70	39.57
		F_3	112.46	78.16	30.50
	Seed yield (g)	F_2	9.33	5.10	45.34
		F_3	89.02	88.41	00.69
	Harvest index (%)	F_2	51.15	24.46	52.18
		F_3	46.37	53.97	-16.39
Cross 3	Pods /plant	F_2	37.40	21.50	42.51
		F_3	61.68	58.29	05.50
	Seeds/plant	F_2	55.60	33.80	39.10
		F_3	79.91	78.16	02.19
	Seed yield (g)	F_2	12.20	1.50	87.70
		F_3	121.35	92.63	23.67
	Harvest index (%)	F_2	41.85	21.50	48.63
		F_3	55.57	64.74	-16.50
Cross 4	Pods /plant	F_2	51.50	31.60	38.64
		F_3	75.98	65.52	13.77
	Seeds/plant	F_2	68.80	47.80	30.52
		F_3	109.17	82.00	24.89
	Seed yield (g)	F_2	6.50	2.00	69.23
		F_3	81.85	79.91	02.37
	Harvest index (%)	F_2	37.63	21.42	43.08
		F_3	48.69	58.11	-19.35
Cross 5	Pods /plant	F_2	47.70	32.60	31.66
		F_3	78.38	50.16	36.00
	Seeds/plant	F_2	58.50	39.60	32.31
		F_3	97.65	63.44	35.03
	Seed yield (g)	F_2	8.25	5.03	39.03
		F_3	104.20	95.12	08.71
	Harvest index (%)	F_2	38.58	25.25	34.55
		F_3	41.99	40.94	02.50

§ cross codes as per Table 1

Inter-generation analyses

The values of heritability between F_2 and F_3 generation were lower in all the crosses for studied characters (Table 4). However, pods per plant exhibited as high as 38 per cent heritability in the Cross 5. This character in the same cross showed high magnitude of genetic advance as percentage of mean (>20 %). Other characters and crosses expressed low heritability and genetic advance. Correlation between F_2 and F_3 generation (Table 4) was highly significant and positive for pods per plant in two crosses (0.66- 0.78) and seeds per plant in three crosses (0.62 - 0.71). However, highly significant negative correlation was occurred for harvest index in the Cross 3 (-0.64).

Table 4. Estimation of intergeneration (F_2/F_3) heritability, genetic advance (GA) and correlation coefficient for four characters in five chickpea crosses

Crosses/Characters	Cross 1§	Cross 2	Cross 3	Cross 4	Cross 5
Pods/plant					
Heritability	0.07	0.31	0.04	0.34	0.38
GA as % Mean	2.85	19.37	2.44	12.80	21.07
Correlation	0.10	0.66**	0.09	0.45*	0.78**
Seeds/plant					
Heritability	0.11	0.31	0.04	0.30	0.28
GA as % Mean	3.98	17.59	2.07	14.15	16.56
Correlation	0.21	0.64**	0.07	0.62**	0.71**
Seed yield (g)					
Heritability	0.10	0.01	0.08	0.01	0.01
GA as % Mean	5.32	0.14	4.52	0.20	0.41
Correlation	0.55**	0.03	0.45*	0.04	0.11
Harvest index (%)					
Heritability	-0.65	-0.60	-0.84	-0.26	-0.01
GA as % Mean	-14.59	-22.55	-22.26	-11.75	-0.29
Correlation	-0.45**	-0.45*	-0.64**	-0.38	-0.01

§ cross codes as per Table 1
*and** represent significant values at p=0.05 and p=0.01 probability levels, respectively

Direct and indirect selection for seed yield improvement

Mean seed yield of F_3 lines derived from direct selection for seed yield itself and indirect selection via yield components (Table 5) shows that differences in high and low group mean were significant in all the crosses when indirect selection via pods per plant was practiced (difference varied from 17.4 g to 39.3 g). Similarly, difference was found significant when selection was exercised for seeds per plant in the Cross 2 (24.7g), Cross 4 (18.9 g) and Cross 5(36.3 g), and for harvest index in the Cross 1(22.2g), Cross 3(20.9 g) and Cross 5(12.5 g). In case of direct selection for seed yield itself, the seed yield difference between high and low F_3 lines found significant in the Cross 1(27.6 g) and Cross 3(28.8 g).

Table 5. Mean seed yield of F_3 lines from high and low selection group and seed yield response from direct and indirect selection for yield and its components in five chickpea crosses

Character selected	Group	Cross 1§	Cross 2	Cross 3	Cross 4	Cross 5
Pods/ plant	High	117.7	106.6	119.2	91.0	119.8
	Low	98.9	72.1	101.8	70.8	80.5
	Diff.	18.8*	34.5*	17.4*	20.2*	39.3*
Seeds/plant	High	114.4	106.5	104.9	90.7	117.8
	Low	111.8	81.8	103.9	71.8	81.5
	Diff.	2.6	24.7*	1.0	18.9*	36.3*
Seed yield (g)	High	120.1	89.0	121.4	81.9	104.2
	Low	92.5	88.4	92.6	79.9	95.1
	Diff.	27.6**	0.60	28.8*	2.0	9.1
Harvest index (%)	High	124.9	88.0	122.8	82.3	103.8
	Low	102.7	86.4	101.9	80.5	91.3
	Diff.	22.2**	1.6	20.9*	1.8	12.5*

§ cross codes as per Table 1, Diff. = Difference between high and low group
*and** represent significant values at p=0.05 and p=0.01 probability levels, respectively

Identification of superior lines

Effectiveness of early generation selection can be measured by identifying superior lines for each selection scheme. For this purpose, the highest yielding 10 F_3 lines from each cross were isolated and traced to F_2 plant selected for high or low expression (Table 6). Out of 10 highest yielding lines in the Cross 1, a maximum of four superior lines were derived from F_2 plants selected for high harvest index.

Table 6. Ten highest yielding F_2 selected F_3 lines and the pattern of selection group of their parental F_2 plants in five chickpea crosses

Crosses[§]	Progeny No.	F_3 yield (g/plot)	Traits selected in F_2			
			Pods/ plant	Seeds / plant	Seed yield(g)	Harvest index (%)
Cross 1	004	170.24	H	NS	H	H
	034	170.23	NS	L	NS	NS
	015	157.93	NS	NS	NS	H
	005	144.70	H	H	H	NS
	035	131.06	NS	NS	NS	L
	024	129.91	L	L	L	NS
	029	126.18	L	NS	L	L
	003	124.45	H	H	H	H
	033	124.45	NS	L	NS	NS
	019	121.22	NS	NS	NS	H
High selection group total			3	2	3	4
Cross 2	045	130.04	H	NS	H	NS
	049	130.03	NS	H	NS	NS
	038	119.14	H	H	H	H
	058	118.99	NS	NS	NS	H
	043	118.90	H	H	H	H
	075	118.90	NS	NS	L	NS
	040	110.07	H	H	H	NS
	079	109.34	NS	NS	NS	L
	053	106.43	NS	NS	H	NS
	042	105.53	H	H	NS	NS
High selection group total			5	5	5	3
Cross 3	109	191.65	NS	NS	NS	H
	102	185.93	NS	NS	H	NS
	107	184.05	NS	NS	NS	H
	091	181.69	H	NS	NS	NS
	098	181.69	NS	H	NS	NS
	101	177.33	NS	NS	H	NS
	089	171.81	H	H	NS	NS
	103	166.68	NS	NS	NS	H
	085	157.68	H	NS	H	NS
	122	127.93	L	L	L	NS
High selection group total			3	2	3	3
Cross 4	146	126.26	H	H	NS	NS
	185	126.25	NS	NS	NS	L
	138	112.54	H	H	H	NS
	150	112.53	NS	NS	H	NS
	158	112.52	NS	NS	NS	H
	183	100.80	NS	NS	NS	L
	145	94.81	H	NS	H	NS
	179	94.80	NS	NS	L	NS
	147	94.79	NS	H	NS	NS
	140	93.79	H	H	NS	H
High selection group total			4	4	3	2
Cross 5	188	146.07	H	H	NS	NS
	223	146.06	NS	NS	L	NS
	194	145.70	H	H	NS	NS
	205	140.48	NS	NS	NS	H
	195	136.72	H	H	H	NS
	207	136.71	NS	NS	NS	H
	187	136.58	H	H	H	H
	222	127.34	NS	NS	L	NS
	186	121.86	H	H	NS	H
	204	118.69	NS	NS	NS	H
High selection group total			5	5	2	5
Overall total of high selection group			20/50	18/50	16/50	17/50
Proportion (%)			40	36	32	34

[§] cross codes as per Tale 1
High, low and non selected are designated by H, L and NS, respectively

Similarly, maximum of five superior lines each traced to high pod number, high seed number and high seed yield in the Cross 2, four lines each traced to high pod number and high seed number in the Cross 4, and five lines each traced to high pod number , high seed number and high harvest index in the Cross 5. Out of 50 highest yielding lines across the crosses, 20 lines (40%) and 18 lines (36%) were derived from F_2 plants selected for high pod number and high seed number, respectively. However, the best top yielding five lines across the crosses were identified from the Cross 3 only.

DISCUSSION

Mean and CV for yield and its components of F_2 populations and their F_3 selected progenies of high and low selection groups (Table 1) were estimated either on plant basis or on plot basis. An effect of selection was measured in terms of difference between the values of F_2 and F_3 generations. A perusals of the table indicated that mean values of F_3 progenies were greater than those of F_2 plants. This is possible because of seasonal variations, as both the generations were grown in two consecutive years. Favourable season may be provided to F_3 generation as mean value of both high and low groups were higher than F_2 mean for pods per plant, seeds per plant and harvest index. Examination of F_3 selected progeny means revealed that selection for high pod number maintained their performance higher than low pod number. Similar trend was also observed for seeds per plant and seed yield. Harvest index showed the contrast results as the mean value of high selection group was lower than that of low selection group in all the crosses, except Cross 5. This suggests that harvest index may be under the pronounced environmental effect and probably means that the superior of individual selection made in F_2 for high expression was more due to environment than due to genotype.

A value of coefficient of variation (CV) provides the information about presence of variability in a test population. The CV values found to be increased in F_3 lines either for high or low or for both in most cases compared to those estimated in F_2 generation (Table 1). For example, seed yield showed higher CV in four crosses for both high and low F_3 progenies and in one cross for low F_3 progenies. Similarly, higher CV for seeds per plant was estimated in three crosses for both selection group and in one cross each for high and low F_3 progenies. Boerma and Cooper (1974) have observed decreasing coefficient of genetic variability with each generation of selection in four soybean crosses. Unexpectedly increasing variability with successive generation of selection in the present study may be due to predominant repulsion phase linkage (Hanson, 1959). However, the possibility of genetic differentiation for increasing variance due to inbreeding in successive generation can not be ruled out (Khalifa and Qualset, 1975).

One of our objectives was to know the impact of F_2 selection on the association of seed yield and its components in succeeding generation (Table 2). As both the generations were grown in consecutive seasons, the results may be influenced by season differences. However, increase or decrease in correlation values with advancement of generation was considered to be indicative of effects of high and low selection of each selection criterion. This was realized to some extent. The significant correlation of pods per plant with seeds per plant and seed yield, and between seeds per plant and seed yield in F_2 became stronger in F_3 generation of all the crosses, except pods per plant with seed yield in the Cross 4. These changes may most probably be due to directional selection operated with high and low groups, though the influence of season difference on the results should be taken into consideration. Selection for pods per plant, seeds per plant and seed yield might have of good impact on seed yield improvement and effectiveness of indirect selection. Increasing magnitude of correlation among different traits with advancement of generation has been reported by Salimath and Patil (1990) in chickpea and Whan *et al.* (1981) in wheat. Effect of F_2 selection on correlation of harvest index with other traits in F_3 was observed to be cross dependent. For example, harvest index and pods per plant in F_2 generation showed significant positive correlation in three crosses and significant negative in two crosses. Out of these five F_2 correlations, three became non-significant with opposite sign in F_3 generation, while Cross 4 showed shifting of significant positive F_2 correlation to significant negative F_3 correlation. Kishore and Gupta (2002) reported that if one association is positive for a particular cross in one generation, then the same association may be negative for the same cross in the succeeding generation. Such difference in correlation between characters from generation to generation may be possible because of the high degree of segregation and genetic heterozygosity in the F_3 generation leading to the breakdown and formation of new linkages (Kishore and Gupta, 2002).

The difference between high and low selected traits in F_2 and F_3 is considered as expected and actual response to selection, respectively, for that particular trait. With few exceptions, reduction in per cent mean difference in F_3 compare to that of F_2 was observed for all the characters (Table 3). This difference was even negative when selection was conducted for harvest index. Early generation selection for harvest index could mislead due to genotype x environment interaction. Similar observations have been reported by Whan *et al.* (1982) in wheat. The per cent difference in F_3 than F_2 was relatively larger for pod number, seed number and seed yield. This indicates that selection for these characters would be effective. However, one has to consider presence of genotype x environment interaction at the great extent, low heritability and inter genotypic competition among individuals within a selected heterogeneous line which affects the effectiveness of early generation selection (Gedge *et al.*, 1978). Parent-progeny correlation as well as intergeneration heritability and genetic advance as percentage of mean in five chickpea crosses worked out based on two successive generations *viz.*, F_2 and F_3 (Table 4), revealed that the heritability estimates were low (> 0.40) for all the characters under consideration. The magnitude of genetic advance as percentage of mean for pods per plant was high (>20) in the Cross 5 and moderate (in between 10 to 20) in the Cross 2 and Cross 4. Generally speaking, heritability and genetic advances between F_2 and F_3 generations for the characters under study were low enough to conclude that their selection would be least effective in early generation.

Correlation between F_2 and F_3 generation (Table 5) varied depending upon the cross combination tested but often non-significant. However, significant positive values for pods per plant and seeds per plant were observed in three crosses and for seed yield in two crosses, which indicate the effectiveness of selecting F_2 plants in a particular genetic background. Harvest index showed significant negative correlations in three crosses. Often non-significant inter-generation correlation for seed yield has been reported by Rahman and Bahl (1986) in chickpea. Since weak or negative intergeneration relationships was observed for the measured traits and strong positive associations found to be established among seed yield, pods per plant and seeds per plant within F_2 and F_3 generation (Table 2), one can expect the involvement of genotype x environment interaction. Genotype x environment interaction tends to reduce the correlation between generations, especially when one is evaluating early generation material for seed yield (O'Brien *et al*., 1978). Whan *et al*. (1981) concluded that while gains in wheat yield can be achieved by selecting for yield in early generations, a foremost consideration needs to be the influence of different sites and years on the effectiveness of selection.

It is assumed that selection of high expression for seed yield and its components usually resulted in greater seed yield than did selection for low expression. We studied effectiveness of yield component selection by measuring the response in terms of seed yield in subsequent generation. Selection was considered effective when the mean seed yield of high and low F_3 lines differed significantly from each other (Table 5). In general, selection for seed yield and its components resulted in a positive response to yield, which ranged from 1.6 g to 39.3 g per plot. It is evident that effectiveness of selection may differ substantially in different populations and that selection may actually lead to little yield gain. Nevertheless, large yield response brought about by selection for pods per plant in the Cross 5 with a mean difference in yield of 39.3g between the high and low pod number lines. This was larger than the gain from selection for yield itself in any population. Kumar and Bahl (1992) observed large yield gain through component selection rather than direct selection in certain chickpea populations under study. Pods per plant selection criterion showed significant mean seed yield difference in all the crosses. Selection for harvest index and seed yield itself gave significant positive yield response by more than 20.9g in the Cross 1 and Cross 3. These results show that selection for high pods per plant is effective, whereas selection for high harvest index and high seed yield may be rewarding only in certain genetic background. Kumar and Bahl (1992) suggested that indirect selection *via* pod number is more efficient than direct selection for seed yield in chickpea. The selection pattern of the individual parent F_2 plant of the 10 highest yielding F_3 progenies could give an idea of the relative effectiveness of the different selection criteria used in the study. Among the 10 highest yielding F_3 lines belonging to five crosses, 40 % lines were derived from F_2 plants selected for high pod number (Table 6). Selection in F_2 plants for high seed number was the second most important criterion. It may be noted that the success of high pod number as selection criterion in F_2 generation was remarkable even though selection carried out in one year with response measured in the succeeding year. This also assumes importance since effects of differing years and selfing (Kishore and Gupta, 2002).

One progeny (003) in the Cross 1, two progenies (038 and 043) in the Cross 2 and one progeny (187) in the Cross 5 belonged to common F_2 plant selection for high expression of all the four selection criteria (Table 7). In contrast, F_3 progenies 034, 035 and 033 of the Cross 1, 075 and 079 of the Cross 2, 185,183 and 179 of the Cross 4 and 223 and 222 of the Cross 5 were derived from F_2 selected low plants for any one of the measured traits and not selected for any other characters. This shows that an optimum balance of those characters possessing neither high nor low expression may be resulted in high yielding lines (Alexander *et al*., 1984; Singh and Balyan, 2003). The best five F_3 progenies (109, 102, 107, 091 and 098) across the crosses are all from the Cross 3. These individual progenies derived from F_2 plants those were selected for one high expression of different characters and not selected for other selection criterion. This suggests that there was no definite pattern of identification of superior yielding lines by selecting for one or more trait(s) even within a population. Such variation in the results may be attributed to the genotype x year interaction or may be due to failure of heterozygous high yielding genotypes to breed true because of segregation in the succeeding generations (Singh and Balyan 2003).

Conclusion

The results of this study suggested that the effectiveness of selection involving the measured traits varied from cross to cross. However, selection for pod number usually found more effective than the other selection criteria. Some superior yielding lines were identified by selection for all the traits; whereas, yield increment in some of the progenies was observed even in the absence of traits selected for high expression.

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