Theor Appl Genet (1985) 70:661–666

Effectiveness of selection methods in chickpea *Cicer arietinum* under different environments *

M. S. Bisen, S. P. Singh and S. K. Rao
J. N. Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh, India

Received January 31, 1984; Accepted February 20, 1984
Communicated by J. MacKey

Summary. Three selection procedures, single-seed-descent, selection of the best 5% in both seed size and seed yield per plant were followed in two divergent crosses of chickpea under four environments in order to study the improvement of seed yield. Analysis of variance showed wide ranges of variability for all characters except days to maturity. Seed size (SSB) was found to be superior to single seed (SSD), followed by seed yield (YB), for developing high yielding lines. Fertility and spacing had no influence on the efficiency of any selection procedure indicating that selection under any environment is equally good.

Key words: Fertility – Spacing – Response to selection – Genetic improvement

Introduction

Chickpea (*Cicer arietinum* L.) is a major pulse crop not only in Madhya Pradesh but in the entire country. Little attention has been paid in the past towards its genetic improvement. So far no information is available regarding breeding methodology and efficiency of selection methods and their interaction and interrelationship with spacing and fertility. Such data could lead to its rapid genetic improvement.

It is unfortunate that the majority of breeding experiments having the objective of studying the genetic analysis of yield and its components remained only as examples in several crops. Very few experiments have been carried out in advanced generations to see the response to selection and to establish efficient breeding procedures in different crops. It is not easy to follow elaborate procedures for the development of high yielding lines in self-pollinated crops. Such procedures are time-consuming and expensive. A breeder has to isolate some of the promising lines based on certain parameters in the early generations. Similarly, the suitability of early generation selection procedures under different environments has not been adequately tested. The concept of early generation testing has been used in several crops: Harlan et al. (1940) in barley, Harrington (1940) in wheat, Immer (1941) in barley, Atkins (1953) in barley, Brim (1966) in soybean, Frey (1968) in oats, Empig and Fehr (1971) in soybean, Tee and Qualset (1975) in wheat, Hamblin et al. (1975) in beans, Knott and Kumar (1975) in wheat, Qualset (1977) in wheat, Haddad and Muehlbauer (1978) in lentils, Rao (1980) in linseed and Knott (1979) in wheat.

The present study was undertaken to explore the practical utility of three breeding methods (SSD, YB and SSB) in two diverse crosses of chickpea under four environments.

* A part of the Ph.D. Thesis submitted to J. N. Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh, India

Materials and methods

This investigation was carried out at the Research Station of Jawaharlal Nehru Agriculture University, Jabalpur, Madhya Pradesh (India) in the growing seasons of 1974/75 to 1977/78. The initial material consisted of two crosses of chickpea, i.e., 'Chaffa' × 'JG82' and 'JG897' × 'N59'. The parents involved in the two crosses were divergent for seed size and seed yield. The material was advanced from the F_2 to the F_5 generation following the scheme given in Fig. 1. The evaluation experiment of forty different populations, consisting of 24 F_5 single plant seed bulks, 8 F_4 seed bulks, 2 F_3 seed bulks, 4 parents and 2 improved varieties, was performed in randomised complete block design with four replications. The plot consisted of 4 rows, each 4 m long, placed 30 cm apart; plant to plant distance was 10 cm. Five competitive plants were tagged per plot to record number of seeds, hundred seed weight and seed yield per plant. The analysis of variance for various characters was carried out for different populations. The structure of analysis of variance for the design of the experiment was partitioned to get the first, second and third order interactions of variances for 40 populations were calculated as per the conventional method.

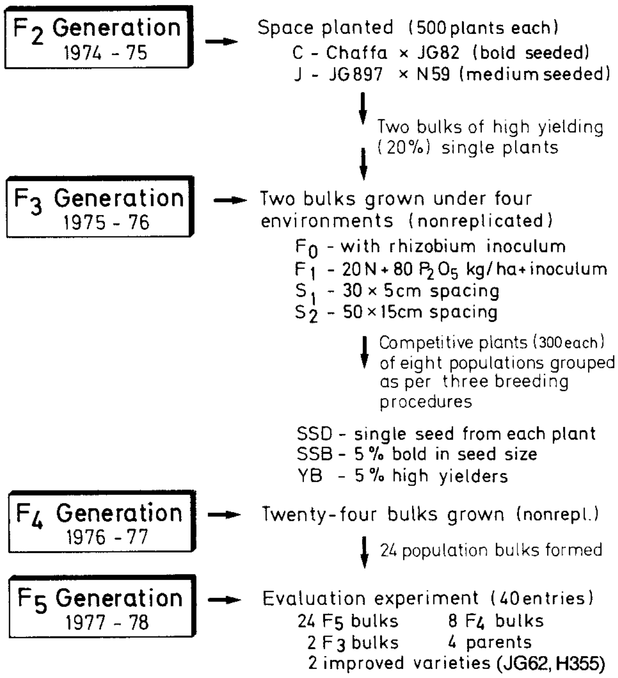

Fig. 1. Selection procedure for segregating populations of chickpea

Results and discussion

The analysis of variance for different characters has been given in Table 1. Significant variability was observed among these groups for all characters and also in different groups and their interaction variances. Overall the analysis of variance, mean values and parameters of variation revealed considerable genotypic variability for all characters-which is a primary requirement for selection in further generations.

Ranges, means and phenotypic variances of group I (two improved varieties), four parents of two crosses in group II and F_3 generations of two crosses for different characters are shown in Table 2. The parents involved in the two crosses showed a considerable range of variation for all characters. It is worth mentioning here that the parents 'Chaffa' and 'JG82' were widely different in seed size. Whereas the parents involved in the other cross ('JG897' and 'N59') showed only small differences in seed size.

Many other breeders have confirmed this observation that for higher selection gains, parents used in the cross should be widely different for the character under improvement. Frey (1968) reported that a screening technique for bolder seeds increased seed weight by 0.1 g per hundred seeds per generation in oats. However, the genotypes 'JG82' recorded the highest mean seed yield per plant (15.73 g) with bolder seed size (30.15 g) followed by 'N59' which had a mean seed/plant of 14.96 g and mean hundred seed weight of 26.95 g. Substantial genetic variability was observed as evidenced by the high mean values of the F_3 bulks for all characters.

Ranges, means and phenotypic variances for two crosses under two fertility levels and two spacings in the F_4 generation are given in Table 3. The population CF_0S_2 recorded the highest mean value for seeds per plant (21.61) associated with the maximum variation (33.85), followed by the CF_1S_1 population (mean value 18.18 and variance 13.67). Comparing two crosses at two fertility levels and two spacings revealed a maximum range of potential variability for all characters in the cross 'Chaffa' × 'JG82'. The four populations of the cross 'JG897' × 'N59' possessed the lowest range of variation and mean values for all characters. In general, fertilizer had no effect on yield and its components. Among the four populations of the cross 'JG897' × 'N59', JF_0S_1 recorded the highest hundred seed weight (19.17 g) associated with the maximum range of variation (4.66), followed by JF_0S_2 with a variance of 3.63.

Ranges, means and phenotypic variances for two crosses under two fertility levels, two spacings and three breeding methods in F_5 generations are presented in Table 4. In the CF_0S_1 population SSB recorded the highest mean seed yield per plant (12.76 g) and also maintained the maximum range of variation (16.16). The highest mean seed yield/plant of the SSB population was attributed as being mainly due to its major yield components. Next to the SSB population, the SSD population recorded the highest mean seed yield per plant (14.66 g) with a variance of 5.78.

In CF_1S_1 the highest mean seed yield/plant (21.52 g) with the variance of 26.05 was recorded in the SSB population. The mean hundred seed weight of this population was 33.01 g with a variance of 35.62. Next to the SSB population the YB population recorded a higher mean seed yield of 16.82 g, which is quite comparable to that of the SSD population (16.32 g). The variance of seed yield for YB was considerably higher (33.83) in comparison to that of either SSB (26.05) or SSD (16.16). The SSD population had a higher mean value of seed size (26.86 g) in comparison to those from the YB population (21.29 g). One of the important features of the former population was that the SSB maintained a wide range of variation for seed size as evidenced by high mean values of seed size and seed yield/plant associated with a maximum range of variation for seed size (35.62). The high mean seed yield observed in the SSB population was mainly attributed to seed size.

From the CF_1S_2 population, SSB recorded the highest mean seed yield/plant (17.91 g) with a variance of 16.25 followed by SSD (15.73 g) with a variance of 9.36. Though the mean seed yield/plant for YB was the lowest (13.37 g), it showed considerably higher variation for mean seed yield (14.56 g) in comparison to SSD. The SSB population had the highest value of 29.21 g for seed size coupled with the lowest range of

Table 1. Partitioned analysis of variance (mean squares) for crosses fertility levels × spacings × breeding methods for different characters

Characters / Source of variation	Degrees of freedom	No. of seeds/plant	100 seed/ wt/plant (g)	Seed yield/ plant (g)
(A) Between groups	4	70.49**	40.86**	37.03**
(B) Within group I	1	197.01**	1.54*	1.31
(C) Within group II	3	56.65**	25.85**	2.16**
(D) Within group III	1	23.81**	14.99**	1.63*
(E) Within group IV	7	59.10**	38.14**	16.27**
Cr	1	1.51	231.02**	88.41**
F	1	20.72**	25.47**	3.76**
Cr × F	1	30.13**	3.50**	0.06
Sp	1	33.72**	0.13	3.70**
Cr × Sp	1	81.76**	0.50	6.69**
F × Sp	1	149.18**	2.39**	11.24**
Cr × F × Sp	1	96.43**	3.97**	0.04
(F) Within group V	23	60.51**	20.75**	6.44**
Cr	1	406.11**	220.30**	30.05**
F	1	10.48**	0.34	2.94**
Bm	2	10.05**	99.46**	31.68**
Cr × F	1	0.18	0.10	0.49
Cr × Bm	2	76.27**	6.26**	7.95**
Bm × F	2	95.72**	2.25**	2.84**
Cr × Bm × F	2	15.56**	6.53**	0.17
Sp	1	2.00	0.59	0.03
Cr × Sp	1	68.26**	2.20**	1.91*
Sp × F	1	80.21**	6.94**	10.58**
Bm × Sp	2	18.67**	1.46*	0.02
Cr × F × Sp	1	0.12	3.76**	3.07**
Cr × Bm × Sp	2	100.56**	4.89**	4.06**
Bm × F × Sp	2	45.54**	0.18	2.13**
Cr × Bm × F × Sp	2	2.90	0.53	1.22
(G) Error	117	2.28	0.76	0.81

Cr = Cross; F = Fertility levels; S = Spacing; Bm = breeding methods
* Significant at 0.05 level of probability; ** Significant at 0.05 level of probability

variation (2.77) followed by SSD having a mean seed size of 27.89 g and a variance of 21.37. Similarly, the lowest mean value for seed size (21.67 g) and variance (5.76) was observed in YB. The lowest mean seed yield of the YB population was mainly attributed as being due to seed size though its other major yield components, i.e., number of seeds, are quite comparable with that of SSB. In this latter population, further improvement in yield can be achieved by selecting for yield components other than seed size because the variation for seed size of this population is very low (2.77).

In the JF_0S_1 population SSB recorded the highest mean seed yield per plant (14.81 g) but it was not significantly superior to SSD (14.08 g). However, the variance of the SSB population for mean seed yield was the lowest (5.06) whereas it was 11.41 in YB and 15.45 in SSD. The mean seed size of the SSB population was 23.87 g which was significantly superior to that of the SSD and YB populations. Non-significant differences were observed for seed size for SSD and YB procedures but the variance of the latter was found to be higher (12.51) when compared to other breeding methods. The slight increase in the mean seed yield of the SSB procedure was mainly attributed to seed size. The selection for seed size drastically reduced the yield components in the SSB procedure.

The SSB procedure in the JF_0S_2 populations retained high yielding lines as evidenced by high mean values of seed yield/plant (15.52 g) with a variance of 19.05. The SSD population recorded the highest mean seed size (22.08 g) in comparison to that of the SSB (21.94 g). The variances for seed yield (12.08) and seed size (8.14) for SSD was found to be intermediate among the three breeding procedures. The lowest mean seed yield/plant (13.62 g) and seed size (18.56 g) was observed for YB. The variations of mean seed yield/plant of three breeding procedures was mainly attributed to variation

Table 2. Ranges, means and phenotypic variances for different groups of genotypes in chickpea

Characters / Genotypes		No. of seeds/ plant	100 seed wt/plant (g)	Seed yield/ plant (g)
Group-I				
JG 62	Range	49–78	13–19	7–12
	Mean	56.90	15.42	8.69
	Variance	49.57	1.72	1.59
H 355	R	11–21	11–21	6–14
	M	76.75	13.67	10.31
	V	257.78	6.18	3.74
Group-II				
Chaffa	R	47–104	14–24	8–18
	M	68.90	18.53	12.62
	V	236.31	8.08	7.45
JG 82	R	47–74	27–35	13–23
	M	52.15	30.15	15.73
	V	56.98	3.55	6.61
JG 897	R	44–89	18–29	8–20
	M	56.85	22.50	12.76
	V	153.50	6.31	8.31
N 59	R	35–80	19–35	9–20
	M	54.05	26.95	14.36
	V	143.73	12.61	6.93
Group-III				
CF_3	R	42–130	22–35	9–29
	M	63.25	25.57	15.88
	V	439.25	11.26	20.35
JF_3	R	40–108	14–22	7–21
	M	70.35	20.09	14.08
	V	471.19	5.43	20.06

Table 3. Ranges, means and phenotypic variances for two crosses under two fertility levels and two spacings in F_4 generation in group V

Characters / F_4 populations		No. of seeds/ plant	100 seed wt/plant (g)	Seed yield/ plant (g)
CF_0S_1	Range	47–73	25–38	14–24
	Mean	55.50	29.28	16.20
	Variance	66.47	6.17	5.85
CF_0S_2	R	38–115	24–39	13–32
	M	67.70	32.53	21.61
	V	458.75	12.93	33.85
CF_2S_1	R	34–95	19–38	6–26
	M	64.30	26.89	17.23
	V	174.70	18.90	14.05
CF_1S_2	R	45–120	20–32	12–30
	M	73.10	25.14	18.18
	V	287.99	6.07	13.67
JF_0S_1	R	46–74	16–24	9–15
	M	59.70	19.17	11.41
	V	65.91	4.66	3.19
JF_0S_2	R	45–124	17–23	8–21
	M	73.00	18.56	13.45
	V	307.16	3.63	9.47
JF_1S_1	R	48–155	14–19	7–25
	M	75.15	16.54	12.37
	V	520.77	2.89	13.69
JF_1S_2	R	46–100	13–19	7–16
	M	56.75	16.63	9.40
	V	167.15	2.62	4.51

in the seed size and number of seeds/plant. Though the mean number of seeds/plant (73.10) is closer to the values observed in SSB, the variation in seed yield in these two methods was due to variation in seed size.

In the JF_1S_1 population, the SSD procedure showed the highest mean seed yield/plant (15.32 g) with an intermediate variance of 8.59. The SSB procedure showed the lowest mean seed yield/plant (13.69 g), with the lowest variance 3.08. The YB method was found to be intermediate for mean seed yield (14.62 g) and was associated with the maximum variance (17.63). The YB procedure had a mean seed size of 19.53 g with a variance of 6.87. In this population recurrent selection for seed size in SSB may further improve the yield level. Comparision of mean values, ranges and variances of the three selection procedures revealed that the SSD procedure recorded the highest mean values for number of seeds/plant (83.25), and variance of 353.15. The YB procedure retained the maximum range of variability for yield and its components.

In the JF_1S_2 population the highest mean seed yield per plant (16.85 g) and variance (15.38) was recorded in the SSB population. SSB also showed the highest mean seed size (24.67 g) and variance 9.62. A further improvement in this population (JF_1S_2) may be achieved by recurrent selection for yield and seed size in subsequent generations. The YB method recorded a mean yield of 13.27 g with a variance of 9.84. In this population the SSD method had the lowest mean seed yield/plant (12.78 g) with an intermediate variance of 13.96. The mean seed size of SSD was 18.51 g with the lowest variance of 2.70.

From the six lines, i.e., the two improved varieties and four parents involved in the two crosses, 'JG82' recorded the highest seed yield (15.73 g, Table 2). Hence, the comparision of selected populations was made gainst 'JG82' (the superior parent in the cross 'Chaffa'×'JG82'). A relative comparision of the mean seed yield/plant of the twenty-four populations of the F_5 generation of the three breeding methods revealed that the SSB of the cross 'Chaffa'×'JG82' recorded a significantly higher mean seed yield than 'JG82' under four environments.

There was no marked influence of fertility on yield, number of seeds and seed size per plant in either crosses. In cross 'Chaffa'×'JG82', the SSB population

Table 4. Ranges, means and phenotypic variances for two crosses under two fertility levels, two spacings and three breeding methods in F_5 group V

Characters		No of seeds/plant			100 seed wt/plant (g)			Seed yield/plant (g)		
F_5 populations		SSD	YB	SSB	SSD	YB	SSB	SSD	YB	SSB
CF_0S_1	R	44–77	42–65	52–88	22–36	15–27	17–38	11–20	8–14	12–27
	M	56.50	56.50	69.35	26.12	21.47	28.67	14.66	11.53	12.76
	V	73.63	24.79	133.61	13.52	10.46	20.64	5.78	1.93	16.26
CF_0S_2	R	41–85	42–81	43–82	22–37	18–29	25–38	12–24	8–18	15–29
	M	60.40	58.35	59.55	28.46	23.10	32.99	16.97	13.17	19.47
	V	170.67	177.50	145.21	16.05	10.02	11.38	11.58	9.59	13.79
CF_1S_1	R	45–80	48–110	47–85	21–34	13–30	26–46	11–27	9–11	15–35
	M	60.75	77.00	65.70	26.86	21.29	33.01	16.32	16.82	21.52
	V	123.67	267.90	142.54	16.71	21.38	35.62	16.16	33.83	26.05
CF_1S_2	R	41–72	41–110	43–83	19–37	18–27	25–32	12–21	9–25	13–25
	M	57.20	62.40	61.20	27.89	21.67	29.21	15.73	13.37	17.91
	V	128.91	331.83	152.27	21.37	5.76	2.77	9.36	14.56	16.25
JF_0S_1	R	44–125	42–86	50–85	16–24	13–27	21–32	7–22	8–21	12–19
	M	71.16	60.30	62.85	19.97	18.77	23.87	14.08	11.27	14.81
	V	446.87	175.48	144.24	5.86	12.51	8.58	15.45	11.41	5.06
JF_0S_2	R	35–122	48–104	32–129	18–27	15–22	18–27	9–24	7–22	7–23
	M	67.65	70.10	73.00	22.08	18.56	21.94	14.75	13.62	15.52
	V	406.13	211.57	705.79	8.14	3.06	9.06	12.08	10.16	19.05
JF_1S_1	R	53–110	45–123	40–82	15–24	16–26	18–39	9–21	9–28	11–17
	M	83.25	76.05	58.20	18.67	19.53	24.15	15.32	14.62	13.68
	V	353.15	478.58	124.70	6.00	6.87	23.76	8.59	17.63	3.08
JF_1S_2	R	46–121	61–106	33–98	15–22	14–23	21–32	8–24	9–22	9–25
	M	69.55	75.65	69.45	18.51	17.47	24.67	12.78	13.27	16.85
	V	454.47	152.03	307.21	2.70	5.53	9.62	13.96	9.84	15.39
C.D. at 5% for comparing means in Table 2–4				4.189		2.419			2.499	

maintained high yielding lines under four environments. The same procedure also maintained the highest range of variation for seed yield in comparision to SSD and YB. Next to SSB, the SSD ranked second for different environments viz., CF_0S_1, CF_0S_2, CF_1S_2 with the exception of CF_1S_1 where SSD ranked third. In general, the YB procedure was able to retain low yielding lines. The high mean values of seed yield/plant of SSB was mainly attributed as being due to variation in number of seeds/plant. The SSB recorded the highest seed size by virtue of its procedural selection. The highest range of variation in SSB for seed size is unusual because the selection for bolder seed will ultimately reduce the variation in seed size. The maximum variation observed for seed size in the selected populations might be due to segregation of this character.

In 'JG897'×'N59' SSB also proved to be superior for maintaining high yielding lines in JF_0S_1, JF_0S_2 and JF_1S_2. SSD ranked first in maintaining high yielding lines in JF_1S_1; YB was found to be intermediate. In this cross a maximum range of variation for seed size was also observed in SSB. An overall observation of these findings revealed the superiority of SSB over either method. The YB was intermediate, whereas SSD was least effective for retaining high yielding lines, as evidenced by lowest mean seed yield and a lower range of variation for seed size and number of seeds.

These observations are in agreement with the concept of Sneep (1977) that SSD populations would face the problem of genetic drift in the F_3 and F_4 populations and may result in depletion of desirable alleles. The superiority of SSB could be due to bold seeded selection contributing a higher proportion of vigor for the next generation. Under such a situation it is expected that the directional gene frequencies for seed size occurs in the desirable direction in favour of bold seeded types. Similar results have also been reported by Hamblin (1975) in beans, and by Atkin (1953) in barley. The superiority of SSB in chickpea was also reported by Mishra (1976). In this study SSD was found to be intermediate in several occasions. This was in confirmation with the findings of Tee and Qualset (1977) who reported the decreasing as well as increasing trends of genetic variances in SSD of the two wheat crosses in successive generations. Knott and Kumar (1975) compared the procedures involving F_3 yield tests to SSD. The lines obtained by SSD are as good as those obtained by the F_3 yield tests. The indirect selection for seed yield through seed size gave the maximum selection response because seed size is a highly heritable character compared to seed yield. Due to the fact that seed yield is a complex character with low heritability in comparision to other yield components, selection for seed yield has given the lowest response. This shows that direct selection for low heritable characters are not going to bring any improvement in yield. Hence, indirect selection for yield components will be the better criteria for improvement of yield.

In this study the direct selection for seed size (SSB) procedure was found to be superior in maintaining high yielding lines along with bolder size in chickpea. However, the improvement of seed yield through indirect selection for seed size is subject to a few limitations:

1. After the optimum level of seed size is obtained there will not be any improvement in seed yield in continuous selection for seed size because seed size and seed yield would soon show a negative correlation in chickpea. Hence, the optimum seed size for breeding high yielding genotypes has yet to be worked out.

2. The seed size fixed during the continuous selection process leads to a decrease in the variability of seed size, which may not give further scope for selection based on this criteria. Hence, it can be concluded that the SSB selection procedure should be a successful criteria in early generations for the genetic improvement of seed yield in chickpea.

References

Atkins RE (1953) Effect of selection upon bulk hybrid barley populations. Agron J 45:311–314

Brim CA (1966) A modified pedigree method of selection in soybean. Crop Sci 6:220

Empig LT, Fehr WR (1971) Evaluation of methods for generation advance in hybrid soybean populations. Crop Sci 11:51–54

Haddad NI, Muehlbauer PJ (1978) Comparision of random bulk population and single-seed-descent methods for lintill breeding. Agron Abstr 49

Hamblin J, Rowell JG (1975) Breeding implications of the relationships between competitive ability and pure culture yield in self-pollinated gram crops. Euphytica 24:221–228

Harlan HV, Martini MI, Stevens H (1940) A study of methods in barley breeding. USDA Techn Bull 720

Harrington JB (1940) Yielding capacity of wheat crosses as indicated by bulk hybrid tests. Can J Res, Sect C 18: 518–584

Immer FR (1941) Relation between yielding ability and homozygosis in barley crosses. J Am Soc Agron 220

Knott DR (1979) Selection for yield in wheat breeding. Euphytica 28:37–40

Knott DR, Kumar J (1975) Comparision of early generation yield testing and single seed descent procedure in wheat breeding. Crop Sci 17:51–54

Mishra MN (1976) Effect of one generation selection through for selection methods under two environments in gram (*Cicer arietinum*). Unpublished MSc Thesis JNKVV, Jabalpur, Madhya Pradesh, India

Rao SK (1980) Genetic improvement of yield in linseed (*Linum usitatissimum* L.). Unpublished PhD thesis JNKVV, Jabalpur, Madhya Pradesh, India

Qualset CO (1977) Population management for efficient methods of breeding and genetic conservation. In: 3rd Int Congr, SABRAO, Canberra, 12 pp

Sneep J (1977) Selection for yield in early generation of self-fertilizing crops. Euphytica 26:27–30

Tee TS, Qualset CO (1975) Bulk population in wheat breeding comparision of SSD and random bulk methods. Euphytica 24:393–405