Indian J. Genet., **51** (2): 240–245 (1991)

RELATIONSHIPS AMONG THE F_2 TO F_6 GENERATIONS IN CHICKPEA (*CICER ARIETINUM* L.)

GELETU BEJIGA, H. A. VAN RHEENEN,* C. A. JAGADISH AND ONKAR SINGH

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru Andhra Pradesh 502324

(Received: February 19, 1990; accepted: May 30, 1990)

ABSTRACT

An experiment was conducted to determine the relationships among the F_2 to F_6 generations of 9 chickpea crosses (*Cicer arietinum* L.). The F_2 yields had a significant and positive correlation with those of the F_3. The mean yields of the F_2 and F_3 were not associated with the mean seed yield of the F_4, F_5 and F_6. Significant associations among the F_2 to F_6 were found for days to 50% flowering, days to maturity and individual seed mass. From the results, it is concluded that selection based on early generation bulk yield tests may not be effective. The observed inconsistency in performance of different generations may have been caused by genetic shift and breaking of gene linkages.

Key words: *Cicer arietinum*, generations, correlation, early generation testing, selection, inbred bulks.

Chickpea (*Cicer arietinum* L.) is an important pulse crop and occupies about 10 million ha worldwide [1]. However, the average yield is only 675 kg/ha. One reason for this could be the lack of efficient breeding methods to develop high-yielding and stable cultivars. Progress from selection in a self-pollinated crop depends both on the mean of the inbred bulk derived from a cross, as well as on the variation within this inbred bulk. The early-generation multilocational yield-test procedure has been followed for chickpea improvement at the ICRISAT Center [2]. In these tests, F_2 populations of the high-yielding F_1s were tested multilocationally, and the best F_2s were further tested in F_3 multilocational trials to reject poorly performing populations in the F_1, F_2 and F_3 generations. Prediction of the performance of crosses from early-generation yield testing (F_2 and F_3) of chickpea was also possible [3]. Correlations between the yields of the F_2 and F_3, F_2 and F_4, and F_3 and F_4 generations in chickpea were reported to be significant and positive [4]. Significant yield increase in chickpea was also realized from early-generation yield tests, compared with both

*Addressee for correspondence.

visual and random selection [5]. However, poor intergeneration associations were reported for pods per plant and grain yield in chickpea [6]. Conflicting results have been reported in other crops. For instance, the F_2 yield test results were considered as reliable predictors of yield potential of different crosses in wheat [7]. Highly significant positive correlations in one season for F_2 line/F_3 mean, F_3 line/F_4 mean, and F_4 line/F_5 mean yields ($r = 0.51, 0.68$ and 0.78, respectively) were obtained in wheat [8]. Similar results were also reported by others in wheat [9]. However, the use of later generations only was suggested for yield tests in wheat since it attains a reasonable degree of homozygosity [10]. In cowpea, nonsignificant correlations were noted among different generations [11]. Inconsistent associations among generations were found in soybean [12]. The present study has been undertaken, therefore, to investigate the relationships among F_2 to F_6 generations in nine chickpea crosses, and to arrive at implications for chickpea improvement.

MATERIALS AND METHODS

The F_3 progenies of 23 crosses were tested in a replicated yield trial at the ICRISAT Center in 1984. Based on the performance, nine crosses representing a wide range in seed yield were selected (Table 1). A part of the F_4 seeds was used for generation advance to F_5 in 1985, while the remaining was kept in cold storage for use as F_4 seed in the 1986 planting. The F_1 seeds of the nine selected crosses were produced again during the post-rainy season of 1985. Fifty three F_1 seeds for each cross were sown in pots in the greenhouse to produce F_2 seeds. About 120 seeds of F_2, together with all the remnant seeds of F_1 and 90 seeds of F_5 per cross, were sown under rainout shelters to generate F_2, F_3 and F_6 seeds.

The complete set of F_2–F_6 generation bulks of the nine crosses and four control varieties, Annigeri, K 850, BDN 9-3, and 2375, were grown in 7 x 7 balanced lattice design with 4 replications on vertisol at the ICRISAT Center in 1986. The plot size was 4.8 m^2, with 4 rows per plot using 30 x 10 cm inter- and intrarow spacing. Presowing irrigation was given and two seeds per hole were sown on October 23, 1986. Weak seedlings were thinned out 2 weeks after emergence. The second irrigation was given 32

Table 1. Selected chickpea crosses and their performance in the F_3 yield trial of 1984

Cross	Yield (kg/ha)	Rank from 25	Status
RSG 44 x Phule G-7	2020	1	High yielder
JG 1265 x 2375	1940	4	High yielder
JG 1265 x Phule G-7	1930	5	High yielder
Phule G-12 x 2 E	1900	9	Intermediate
ICCC 6 x 2375	1850	11	Intermediate
ICCC 6 x JG 315	1840	12	Intermediate
2375 x JG 315	1540	22	Low yielder
Phule G-12 x 64-3	1490	23	Low yielder
64-3 x BDN 9-3	1350	25	Low yielder
Annigeri (control)	1620	21	
SE	±213		
CV (%)	21		

Source: Chickpea Breeding Program, ICRISAT.

days after planting. Observations were recorded for days to 50% flowering, maturity and seed yield on plot basis, while observations for other characters were recorded on 5 randomly selected plants/plot. The mean of the 5 plants per replication was used for the analysis of variance. The correlations were determined on the entry mean basis.

RESULTS AND DISCUSSION

There were significant differences among the treatments. Most of the crosses had significantly higher mean yields than the two control varieties, Annigeri and BDN 9-3. However, none of the crosses outyielded the control variety K 850 (Table 2). There were no significant differences among the mean yields of the crosses in the F_2 and F_6, while significant differences were obtained among the mean yields of the crosses in the F_3, F_4 and F_5 (Table 2).

Significant positive association (r = 0.67) was observed only between the F_2 and F_3 mean yields (Table 3). Rank switching based on performance was observed for all the crosses in different generations, except for RSG 44 x Phule G-7, which had highest mean seed yield across generations and consistently ranked first in the F_2, F_3 and F_4. Switching in rank based on yield between high and medium and medium and low yielding groups were reported

Table 2. Adjusted mean yield (kg/ha) of the different generations of 9 selected chickpea crosses in 1986

Entry	F_2	F_3	F_4	F_5	F_6	Mean	F_3 Rank
RSG 44 x Phule G-7	2540 (2)[a]	2610 (1)	2360 (8)	2230 (8)	2430 (5)	2430 (2)	1
JG 1265 x 2375	2410 (7)	2340 (6)	2070 (11)	2080 (11)	2430 (4)	2270 (11)	4
JG 1265 x Phule G-7	2440 (5)	2550 (3)	2190 (10)	2300 (6)	2520 (2)	2400 (4)	5
Phule G-12 x 2 E	2380 (8)	2480 (5)	2340 (4)	2240 (7)	2300 (11)	2350 (6)	9
ICCC 6 x 2375	2430 (6)	2270 (10)	2240 (8)	2170 (9)	2330 (9)	2290 (8)	11
ICCC 6 x JG 315	2270 (11)	2340 (6)	2280 (6)	2080 (11)	2460 (3)	2290 (9)	12
2375 x JG 315	2490 (3)	2520 (4)	2210 (9)	2480 (2)	2380 (7)	2410 (3)	22
Phule G-12 x 64-3	2300 (10)	2220 (11)	2350 (3)	2370 (4)	2390 (6)	2330 (7)	23
64-3 x BDN 9-3	2480 (4)	2310 (8)	2280 (6)	2430 (3)	2340 (8)	2370 (5)	25
Controls:							
Annigeri	2040 (13)	2040 (13)	2040 (13)	2040 (13)	2040 (13)	2040 (13)	
K 850	2590 (1)	2590 (2)	2590 (1)	2590 (1)	2590 (1)	2590 (1)	
BDN 9-3	2140 (12)	2140 (12)	2140 (11)	2140 (12)	2140 (12)	2140 (12)	
2375	2310 (9)	2310 (8)	2310 (5)	2310 (10)	2310 (8)	2310 (8)	

SE ± = 101.6; F value = 1.78**; LSD (5%) for 49 entries = 287; LSD (5%) for crosses = 129; LSD (5%) for generations = 96, and CV = 9%.

Note. Numbers in parentheses show the rank of the crosses.

earlier [4], but here it was observed even between high and low. For instance, Phule G-12 x 64-3 ranked 8th in F_2 and 9th in F_3, and 2nd in F_4 and 3rd in F_5. A similar inconsistency was reported in soybean [12]. Therefore, although the F_2 yield test was effective to predict the performance of crosses in the F_3, as was also reported earlier [2, 3] no reliable predictions can be made for the yield performance of later generations from the F_2 or F_3 replicated trial data.

Correlations on entry mean basis were positive between generations for days to 50% flowering and days to maturity, and individual seed weight (Table 4). This consistency may probably enable the breeder to identify crosses with the desirable flowering to maturity period and individual seed weight. Significant associations among the generations were not observed for plant height, primary and secondary branches per plant, and pods and seeds per plant.

Table 3. Correlations among mean yields of F_2 to F_6 generations of 9 selected chickpea crosses

Generations	F_2	F_3	F_4	F_5	F_6
F_2	1.00	0.67*	–0.07	0.52	0.04
F_3		1.00	0.04	0.21	0.43
F_4			1.00	0.09	–0.27
F_5				1.00	–0.23
F_6					1.00

*Significant at 0.05 probability level.

The observed inconsistency in performance of different generations of chickpea crosses is most interesting and unexpected. The cause cannot be the genotype x environment interaction, as the study was conducted in one environment only. Breaking of genetic linkages might have caused changes in performance, and genetic shifts in the various populations during their production cycles might have added to the inconsistency.

The results of this study suggest that the performance of the later generations cannot be predicted because there is an inconsistency in performances of the crosses in different generations. In the present study, no attempt has been made to trace the causes of this instability in performance of the crosses. However, if the single-seed descent method had been used to advance the generations of these crosses, the genetic shifts that might have occurred in these populations could have been minimised.

For practical crop improvement purposes, it might be advisable not to conduct early-generation yield tests among cross bulks, but to select for highly heritable traits with a high correlation over generations.

ACKNOWLEDGEMENTS

The senior author is grateful to the International Development Research Centre (IDRC) for the financial support for this study. He is also thankful to the Andhra Pradesh Agricultural University and ICRISAT for their assistance and for permitting him to use their

Table 4. Correlations for different characters among F_2 to F_6 generations for 9 selected chickpea crosses

Character	Generation	F_2	F_3	F_4	F_5	F_6
Days to 50% flowering	F_2	1.00	0.70**	0.35**	–0.01	0.01
	F_3		1.00	0.55**	0.11	0.41**
	F_4			1.00	0.42**	0.70**
	F_5				1.00	0.39**
	F_6					1.00
Days to maturity	F_2	1.00	0.65**	0.19	–0.21*	0.17
	F_3		1.00	0.60**	0.38**	0.24*
	F_4			1.00	0.66**	0.23*
	F_5				1.00	–0.07
	F_6					1.00
Plant height	F_2	1.00	0.01	–0.19	0.13	0.11
	F_3		1.00	–0.04	0.12	0.17
	F_4			1.00	–0.04	–0.08
	F_5				1.00	–0.03
	F_6					1.00
No. of primary branches	F_2	1.00	0.20	–0.16	–0.01	0.10
	F_3		1.00	–0.00	–0.04	–0.06
	F_4			1.00	0.05	–0.15
	F_5				1.00	0.13
	F_6					1.00
No. of secondary branches	F_2	1.00	0.03	–0.09	–0.04	0.12
	F_3		1.00	0.18	0.04	–0.08
	F_4			1.00	0.06	0.04
	F_5				1.00	–0.16
	F_6					1.00
Pods/plant	F_2	1.00	–0.05	–0.08	0.16	0.08
	F_3		1.00	0.11	–0.02	0.04
	F_4			1.00	–0.15	–0.00
	F_5				1.00	0.02
	F_6					1.00
Seeds/plant	F_2	1.00	0.12	0.07	0.16	–0.01
	F_3		1.00	0.11	0.02	–0.03
	F_4			1.00	–0.12	0.05
	F_5				1.00	–0.05
	F_6					1.00
20-seed wt.	F_2	1.00	0.41**	0.31**	–0.09	0.01
	F_3		1.00	0.27**	–0.05	–0.01
	F_4			1.00	0.21*	0.02
	F_5				1.00	–0.23*
	F_6					1.00
Yield/plant	F_2	1.00	–0.07	–0.02	–0.05	0.07
	F_3		1.00	0.32**	–0.01	–0.11
	F_4			1.00	0.05	0.05
	F_5				1.00	–0.15
	F_6					1.00

*Significant at 5%; **significant at 1%.

facilities. The help and support of the ICRISAT staff, particularly those from Chickpea Breeding and Statistics, are gratefully acknowledged.

REFERENCES

1. FAO. 1985. Production Year Book, vol. 39: 34.

2. J. B. Smithson. 1985. Breeding advances in chickpeas at ICRISAT. *In*: Progress in Plant Breeding (Ed. G. E. Russell). Butterworths, London: 223–237.

3. A. K. Auckland and K. B. Singh. 1977. An international approach to chickpea (*Cicer arietinum* L.) breeding. *In*: Plant Breeding Papers 2. 3rd Intern. Congr. of SABRAO and Australian Plant Breeding Conference, Canberra, Australia: 8–10, 8–13.

4. B. S. Dahiya, I. S. Solanki and K. Ram. 1983. F_2, F_3 and F_4 bulk yields as indications of cross performance. Intern. Chickpea Newsl., **8**: 12–13.

5. B. S. Dahiya, R. S. J. Waldia, L. S. Kaushise and I. S. Solanki. 1984. Early generation yield testing versus visual selection in chickpea (*Cicer arietinum* L.). Theor. Appl. Genet., **68**: 525–529.

6. M. A. Rahman and P. N. Bahl. 1986. Evaluation of early generation testing in chickpea. Pl. Breed., **97**: 82–87.

7. G. S. Bhullar, K. S. Gill and A. S. Ahehra. 1977. Performance of bulk populations and effectiveness of early generation testing in wheat. Indian J. agric. Sci., **47**: 330–332.

8. B. R. Whan, A. J. Rathjen and R. Knight. 1981. The relation between wheat lines derived from the F_2, F_3, F_4 and F_5 generations for grain yield and harvest index. Euphytica, **30**: 419–430.

9. H. G. Nass. 1979. Selecting superior spring wheat crosses in early generation. Euphytica, **28**: 161–167.

10. D. R. Knott and J. Kumar. 1975. Comparison of early generation yield testing and a single seed descent procedure in wheat breeding. Crop Sci., **15**: 295–299.

11. K Virupakshappa. 1984. Evaluation of single seed descent, bulk and pedigree methods in cowpea (*Vigna unguiculata* L. Walp). Mysore J. Agric. Sci., **18**: 76.

12. M. G. Weiss, C. R. Weber and R. R. Kalton. 1947. Early generation testing in soybean. J. Am. Soc. Agron., **39**: 791–811.