Dedicated

to

My late Parents

EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L.)

THESIS SUBMITTED TO
JUNAGADH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT AND REQUIREMENT
FOR THE AWARD OF THE DEGREE

OF

Doctor of Philosophy
(Agriculture)

IN

PLANT BREEDING AND GENETICS

BY

TALAPADA MANSUKHLAL MOHANBHAI
M.Sc. (Agri.)

DEPARTMENT OF GENETICS & PLANT BREEDING
COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH -362001

June-2012
Registration No. J4-00143-2005

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ABSTRACT

EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L.)

Name of the student **Major Advisor**

M. M. Talapada Dr. B. A. Monpara

DEPARTMENT OF GENETICS & PLANT BREEDING
COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH

ABSTRACT

For maximum efficiency and progress in breeding for chickpea, it would be advantageous if effective selection could be carried out in as early a generation as possible so that only best lines would be retained for further testing. Five populations of chickpea were formed by involving seven parents. Ten F_2 plants from each of these crosses were selected for high as well as for low expression of pods per plant, seeds per plant, harvest index and seed yield per plant. The F_3 lines from 226 selected F_2 plants were grown in randomized block design with three replications. Results revealed that selection for high level had maintained their higher expression for pods per plant, seeds per plant and seed yield. Increasing of CV values in F_3 as compared to F_2 generation usually not expected, may be due to the predominant repulsion phase linkage. Correlations among pods per plant,

seeds per plant and seed yield from F_2 generation to derived F_3 lines of them were increased as the generation was advanced.

Realized heritability estimates were inconsistent and cross dependent. Low heritability coupled with low genetic advance and inconsistent correlations of F_2/F_3 generations for the selection criterion indicated the influence of environment on the effectiveness of selection.

Selection for improvement of seed yield using pods per plant was found effective as significant yield difference between high and low level of this trait was observed in all the crosses. However, its effectiveness may be considered as moderately successful because of 40% of high yielding F_3 progenies were derived from F_2 plants with high pod number. In contrast, selection for other components and seed yield itself showed significant yield advantage in certain situations, however, it could not be recommended as routine procedure.

There was no definite pattern for identification of superior yielding lines through selection of yield and its components. Some superior yielding lines were identified by selection for all the traits, whereas, some superior progenies were obtained even in the absence of high expression of all the traits.

It is concluded that while gain in yield can be achieved by selecting for high pod number in early generation, a foremost consideration needs to be the influence of environment on the effectiveness of selection.

Dr. B. A. MONPARA
Research Scientist (Pl. Br.),
Agricultural Research Station,
Junagadh Agricultural University
AMRELI

CERTIFICATE

This is to certify that the thesis entitled **"EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L.)"** submitted by **Mr. TALAPADA MANSUKHLAL MOHANBHAI** to Junagadh in partial fulfillment of the requirement of the degree of Doctor of Philosophy in the subject of **PLANT BREEDING & GENETICS** of Junagadh Agricultural University is a record of bonofide research carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Junagadh **(B. A. Monpara)**
Date : -11- 2012 Major advisor

COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH

CERTIFICATE-I

This is to certify that **Mr. TALAPADA MANSUKHLAL MOHANBHAI** has successfully completed the comprehensive/ preliminary examination held on 00-03-2009 as required under the regulation for post Graduate studies.

Place : Junagadh
Date : -11- 2012

(B. A. Monpara)
Major advisor &
Research Scientist (Pl. Br.),
Agricultural Research Station,
J.A.U., Amreli.

(C. K. Mandavia)
Professor & Head
Deptt. of Genetics & Plant Breeding
College of Agriculture
J.A.U., Junagadh.

COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH

CERTIFICATE-II

This is to certify that the thesis entitled **"EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L.)"** submitted for the degree of Doctor of Philosophy in the subject of **PLANT BREEDING & GENETICS** embodies bonafide research work carried out by **Mr. TALAPADA MANSUKHLAL MOHANBHAI** under my guidance and supervision and of this thesis has been submitted for any other degree. The assistance and held received during the course of investigation have been fully acknowledge.

Place : Junagadh
Date : -11- 2012

(B. A. Monpara)
Major advisor &
Research Scientist (Pl. Br.),
Agricultural Research Station,
J.A.U., Amreli.

(A. V. Barad)
Principal and Dean
College of Agriculture
J.A.U.,Junagadh.

(C. K. Mandavia)
Professor & Head
Deptt. of Genetics & Plant Breeding
College of Agriculture
J.A.U., Junagadh.

COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH

CERTIFICATE- III

This is to certify that the thesis entitled **"EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L)"** submitted by **Mr. TALAPADA MANSUKH MOHANBHAI** to Junagadh Agricultural university, Junagadh in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the subject of **PLANT BREEDING & GENETICS** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory, we there for recommended by that the thesis be approved.

Place : Junagadh
Date : 01 -11- 2012

(B. A. Monpara)
Major advisor
Research Scientist (Pl. Br.)
Agriculture Research Station,
J. A. U.. Amreli.

(B. K. Chovatia)
Minor Advisor
Associate Professor,
Department of Plant Pathology
J. A. U.. Junagadh

(D. U. Patel)
External examiner
Reserch Scientist (Sugarcane)
N. A. U., Navasari

(M. U. Kukadia)
External examiner
Ex. Professor and Head
N. A. U..Navasari

(A. V. Barad)
Principal & Dean
College of Agriculture,
J. A. U.. Junagadh.

Approved by **(C. J. Dangariya)**
Director of Research & Dean P. G. studies
Junagadh Agriculture University,
Junagadh.

COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH

CERTIFICATE- IV

This is to certify that **Mr. TALAPADA MANSUKHLAL MOHANBHAI** student of Doctor of Philosophy in **PLANT BREEDING & GENETICS** Department has made all corrections/ modification in thesis entitled **"EARLY GENERATION SELECTION FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L.)"** as suggested by the external examiner and the advisory committee in the oral examination held on 01-11-2012. The final copies of the thesis duly bound and corrected have been submitted on -11-2012.

Place : Junagadh
Date : -11- 2012

(B. A. Monpara)
Major advisor &
Research Scientist (Pl. Br.),
Agricultural Research Station,
J.A.U., Amreli.

ACKNOWLEDGEMENT

I have pleasure and privilege to express my sence of gratitude to my major advisor Dr. B. A. Monpara, Research Scientist, Agricultural Research Station, Junagadh Agricultural University, Amreli for taking keen and sustained personal interest and giving inspiration throughout the study period and providing guidance and constructive suggestions in preparation of this dissertation.

I wish to express my profound thank to the members of my advisory committee: Dr. B. K. Chovatia, Professor (Plant Pato.): Dr. K. L. Dobaria, Research Scientist (Oilseed): Dr. M. D. Khanpara, Research Scientist (Cotton) and Dr. A. M. Makwana, Associate professor (Horti.) for their constant attention, valuable guidance and help chairing my study.

I am thankful to all the staff members of Department of Genetics and Plant breeding, Plant Pathology and Horticulture and staff members of Main Dry Farming Research Station, Targhadia for their kind help and cooperation with special thank to Dr. D. R. Mehta, Assistant Research Scientist (Pl.Breed) and Dr. Madariya, Assistant Research Scientist (Pl.Breed), Dr. V. J. Bhatia, Associate Research Scientist (Pl.Breed) and Dr. M. V. Bhalala, Associate Research Scientist (Pl.Breed) for his help during thesis writing.

I accord my indebtedness towards Dr. N. C. Patel, the Vice-Chancellor and to Dr. C. J. Dangaria, the Director of Research and Dean, P.G. Studies, Junagadh Agricultural University for giving me an opportunity to improve my career by granting admission for in-service Ph.D. study. I am also grateful to Dr. A. V. Barad, the Principal, College of Agriculture, Junagadh for providing facilities to conduct this study.

My sincere thanks are also due to Dr. K.N. Akabari, Research Scientist, Dry Farming Research Station, Targhadia, Dr. M. D. Khanpara Research Scientist, Cotton Research Station, Junagadh, Dr. H. R. Pandya, Associate professor, Department of statistics, Mr. V. B. Gadhia, Mr. G. B. Vekaria, Mr. P.

N. Rabadia, Dr. D. V. Patel, Mr. Varu, Mr Hingrajia, Mr Shekhva for their help during my research work.

I would like to express my sincere appreciation and gratitude to my wife, Bhavna not only for her encouragement but also for moral support and help in typing the thesis. I also wish to express my special appreciation to my children Darshi and Harsh for devoting their enjoyable time.

I would remiss if I do not express my debt to all my family members including my elder brothers shri Gangadashbhai, shri Ganeshbhai, shri Arjanbhai, shri Rameshbhai and sister Kantaben, for personal sacrifice, everlasting love, moral support and encouragement during the period of my study. Their affectionate love and care cannot be expressed fully.

Place Rajkot

Date: 28-06-2012 *(M. M. TALAPADA)*

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INTRODUCTION

I. INTRODUCTION

Importance of pulses is relatively more in our country as its contribution in nutrient supply is far more in Indian diet than that in Asia and world as a whole (Ali, 2002). Among the pulses, chickpea (*Cicer arietinum* L.) is the most important crop with high acceptability and wider use. Chickpea is one of the first grain legumes to be domesticated by humans in old world (Van der Maesen, 1972) and popularly known as bengal gram in India, garbenzo bean in Latin America, homes and hamaz in Arab World, nohud and lablabi in Turkey and shimbra in Ethiopia. It has been an integral part of Indian agriculture since times immemorial because of its intrinsic value in terms of higher protein, nitrogen fixing ability, diversified uses and indispensability as alternative crop for crop diversification.

Chickpea is a legume plant that grows in subtropical and temperate regions. 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). The *desi* types account for about 85 per cent of total chickpea area, usually have small, angular-shaped, dark coloured seeds with rough surface, pink flowers, anthocyanin pigmentation on the stem, and either semi-erect or semi-spreading growth habit. The *kabuli* type, which cover the remaining 15 per cent area, usually have large "ram's head" – shaped, smooth surface seeds, lack of anthocyanin pigmentation, and semi-spreading growth habit.

Chickpea belongs to the sub-family *papilionaceae* of the family *Fabaceae* (Bentham and Hooker, 1970). The genus consists of 39 known species distributed mainly in central and western Asia of which two species *viz., Cicer arietinum* and *C. soongaricum* are found to be cultivated in India. The origin of the crop is believed to be Western Asia from where it spread in India and other parts of the world. Like other pulses, supplementation of chickpea with cereal based diets is one of the possible options to mitigate the problems associated with protein energy malnutrition. The daily per capita availability of 14 g chickpea is a source of approximately 2.3% (56 Kcal) energy and 4.7% (2.7 g) protein to Indian population besides being a major source of 10-12% calcium and iron. In nutritional viewpoint, chickpea seed contains 12.4-31.5% crude protein, 41.0-50.8% starch, 4.8-8.3% soluble sugars, 52.4-70.9% total carbohydrates, 3.8-10.2% ash, 3.9-9.8% iron and 0.28-0.30% vitamin B_1. Its flour is a major ingredient in a number of snacks and sweets in India. Green immature seeds are used as vegetable.

In India, chickpea covers an area of 8.26 million hectares with the production of 6.2 million tones and productivity of 751 kg/ha (Annon. 2009). Four states *viz.,* Madhya Pradesh, Rajasthan, Uttar Pradesh and Maharashtra together contribute about 87% of the production from 65% area. In Gujarat, it is cultivated in 1.67 lakh hectares with total production of 2.0 – 2.5 lakh tones (Chickpea Research Highlights 2009-2010). Major districts producing chickpea in Gujarat are Dahod, Jamnagar Kutch, Saurashtra and Northern part of Gujarat. The quality as well as the yield of chickpea of Gujarat is the best among all the states of India.

As compared to food grains, the productivity of chickpea in our country is very low. The decreasing *per capita* availability of pulses (69g in 1961 to 37g in 2000) in the country has been a serious concern. To overcome this problem, the chickpea breeders concentrating on the development of varieties resistant to biotic and abiotic stresses.

The basic rationale in any crop improvement programme is to increase the yield potential and for that existence of genetic variability in a particular crop is the key factor. In fact, the character like yield has got a complex gene action and is the end result of the interaction of many attributing traits. In order to study it properly, different traits contributing towards the yield must be considered and evaluated properly.

Restricted genetic variability available for agronomic characters is a major limitation in improvement of pulse crops. At present genes can readily be transferred from *C. reticulatum* to cultivated species. But useful genes from other species of the genus *Cicer* can not be utilized due to incompatibility barriers. It may be hoped that through the development of new techniques such as embryo rescue and somatic hybridization, the desirable genes from other *cicer* species could be introgressed to the cultivated chickpea (Altaf and Ahmed, 1990).

Indeed, the F_2 generation provides an active breeding material from which desirable plants may be selected. If a breeder is to apply selection to a cross population of self fertilizing crop and wishes to maximize his chances of finding a productive genotype, he will have to introduce yield tests in the F_3 line. Sneep (1984) illustrated how the chances for the recovery of a plant with all the desired alleles for yield reduces with advanced generations. Although the percentage of homozygous genotypes increases considerably with advanced generations, the number of plants that are necessarily involved in the selection becomes so large that the size of the population grows beyond manageable limits. Selection for yield and yield components in early generations has produced varying results.

Early generation testing (EGT) as a breeding procedure for autogamous crops consists of testing heterozygous families followed by selection of homozygous lines from superior families. It is often used to identify segregating populations that are expected to contain the greatest frequency of favourable genotypes to eliminate inferior population with limited promise.

Early generation selection or screening is used in the improvement of autogamous species to assess the potential of progenies at early stages (F_2-, F_3- or F_4-). Whan *et al.* (1982) suggested that selection for grain yield in early generation need to be done at many sites simultaneously at an early growth stage. Progenies with a low potential for the traits of interest are therefore eliminated and the efforts being focused on the potentially best genotypes (Fehr 1987). This method is one of the best options to reduce the amount of material to be handled in the segregating generations and hold promise that the performance of a progeny in early generations is a good predictor of the performance of the inbred lines derived thereof (Rex Bernardo 2003).

Keeping above facts in view, present study in chickpea was under taken with the following objectives.

i. To determine variability parameters and correlations among the yield and yield components in F_2 and F_3 generation

ii. To determine response to selection in forms of realized heritability values for yield and its component traits

iii. To assess the relationship between the two successive generations, viz., second (F_2) and third generation (F_3)

iv. To examine the effectiveness of indirect selection based on yield components in terms of yield response

II. REVIEW OF LITERATURE

Early generation selection is a potentially most effective strategy in plant breeding. The efficiency of early generation selection depends on the speed and accuracy with which genotypic value can be measured on the small and often unreplicated samples of available plant material.

Early generation selection in self-pollinated crops typically involves the evaluation of F_2– or F_3–derived lines from the cross between two inbreds. Inferior F_2– or F_3–derived lines are then discarded to allow the expenditure of resources on the testing and selection of more promising lines. The F_2– or F_3–derived lines are far from being homozygous, and early generation selection relies on the assumption that the performance of a line at an early generation of selfing is predictive of its performance at homozygosity.

Different generations have been proposed as the "early" generation in which families can be derived for testing in the first phase. Harlan *et al.* (1940) used yield tests of bulks of 379 barley crosses to identify superior populations from which to select homozygous lines. In their procedure, selection among cross bulks (or, as we prefer, [F_1]-derived families) is the first phase. Weiss *et al.* (1947) used yield of [$F_{2:3}$] families of soybean to predict the performance of more inbred progenies. Frey (1954) and Cooper (1990) also described procedures based on testing [F_2]-derived families. Procedures based on testing [F_3]-derived families were considered by Voigt and Weber (1960) and Thorne (1974).

An F_2 derived line is defined as a line derived from a single F_2 plant, irrespective of the generation in which it is tested. Similarly, an F_3 derived line is a line derived from a single F_3 plant. It implies that the line is carried in bulk in the generations following the single plant, and no reselection has been practiced. An F_2 family includes all lines which can be traced back to a single F_2 plant, including reselections. An F_2 family might include a number of F_3, F_4 and F_5 derived lines and an F_3 family might include F_4 and F_5 derived lines.

The objective of early generation testing is to obtain information on yield potential at the beginning of the selection process. The success of early generation testing depends on the ability to distinguish differences between genotypes in early generations, and that those differences will persist during later generations of selection. Several reports on early generation testing in different crop species have conflicted in the success rate, and no consensus has been reached as to the effectiveness of the procedure (Knott and Kumar, 1975, O'Brien *et al.* 1978, Rahman and Bahl, 1986, Singh *et al.* 1990).

The literature pertaining to present investigation on early generation selection for yield and its components in chickpea is limited. Therefore, related works on other crops have also been reviewed hereunder.

A. Chickpea crop

Four F_3 populations of chickpea were simultaneously evaluated by Dahiya *et al.* (1984) for early generation yield testing *versus* visual selection in chickpea. 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 were 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 improvement in chickpea.

Variability parameters in chickpea were computed by Kambale *et al.* (1984) for seed yield per plant, days to maturity, pods per plant, total dry matter, harvest index and 100-grain weight by growing five strains and 10 F_3 bulks under irrigated as well as rainfed conditions. They reported the presence of significant genetic variability for all the characters studied in both the environments. Pod number per plant, dry matter production per plant, 100-seed weight and seed yield per plant showed moderate to high values of heritability and expected genetic advance in both the environments.

Realized heritability was estimated by Bisen *et al.* (1985) for seed yield in F_4 and F_5 generations from two crosses of chickpea. Three breeding procedures of all eight populations showed high estimates of heritability with the exception of seed size Bulk in CSOF1 (.28). The realized h^2 estimates from different crosses and breeding procedure were quite inconsistent.

Salimath and Bhal (1985) studied early generation selection in chickpea and reported that a selection intensity of 5% was applied to 21 F_2 populations individually for seed yield per plant, pod number per plant, seeds per pod and 100-seed weight. This resulted in 84 F_3 single plant progenies for each of the four characters. Single plant observations made on each of the characters in the F_2 and F_3 were used to calculate predicted and realized responses, both direct and correlated, for seed yield and its components. The gains realized by direct selection for each of the characters were higher than the correlated responses realized for that character, showing that direct selection was more useful. The predicted and realized gains by direct selection for pod number and seed weight were comparable. The correlated responses in pod number when selected for seed weight and in seed weight when selected for seeds per pod and pod number confirmed the predictions.

Rahman and Bahl (1986) calculated inter-generation correlations between F_2-F_3, F_2-F_4 and F_3-F_4 in six crosses of chickpea using individual plant/progeny means. In general, correlation values in case of plant height, seeds per pod and 100-seed weight were higher between F_3 and F_4 than those between F_2 and F_3 and F_2 and F_4. However, inter-generation correlations were mostly non significant in case of pods per plant and grain yield. These results clearly showed that selection in F_3 could be fruitful for seeds per pod and 100-seed weight. However, selection for pods per plant and grain yield in early generations did not show any relationship with later generation performance for these traits.

Kodambi *et al.* (1988) studied seven generations (P_1, P_2, BC_l, BC_2, F_l, F_2, and F_3) of a cross NP 34 x P 1528-1-1 for the computation of correlations among different traits. Days to maturity was related positively with plant height in BC_2, and F_2 but negatively with primary branches in F_3 and with secondary branches in F_2, and F_3. This indicated that selection for more primary and secondary branches per plant, or shorter plant height may result in the early maturing line. Plant height was correlated negatively to primary branches and positively to secondary branches. Primary branches were related to secondary branches in most of the generations suggesting the intrinsic sequential development of these traits. Seed yield per plant was not related either with days to flowering or days to maturity; hence it may be possible to select lines with higher yield and early maturity.

Genetic correlations among the characters were computed by Salimath and Patil (1990) using F_3 and F_4 generations of chickpea. Correlation coefficients were calculated separately for both the generations. They reported that seed yield per plant had strong positive association with pods per plant and seeds per pod, but strong negative association with seed weight (size) and plant height. The magnitude of correlations among different traits increased in F_4 generation. The selection of normal looking plants at random for advancing the generation accounts for the general improvement in chickpea.

The efficiency of indirect selection for seed yield was compared with direct selection for yield *per se* in chickpea by Kumar and Bahl (1992). A total of 2500 single F_2 plants, derived from 50 crosses with 50 plants from each cross, dividing into five sub-populations (SP1 to SP5) of 500 plants each by including 10 plants from each of the 50 crosses. The five sub-populations were advanced up to F_6 by exercising 10% selection intensity for four successive generations for number of pods per plant in SP1, number of seeds per pod in SP2, seed weight in SP3, seed yield in SP4 and random selection in SP5. The efficiency of direct and indirect selection for yield was evaluated by comparing groups of 50 F_6 lines from each sub-population. SP1 and SP3 F_6 lines showed higher mean grain yield than the other three methods. SP1 and SP3 were found to be almost equally efficient in developing F_6 lines which were significantly superior to the check. They suggested that indirect selection *via* pod number and seed weight was more efficient than direct selection for yield.

Nagaraj *et al.* (2002a) studied the nature and magnitude of correlations among various characters in the biparental progenies (BIPs) and selfed generation (F_3) of chickpea. Analysis revealed that the correlation coefficients in BIP were generally higher than those obtained in F_3. However, in both populations, the association between the number of pods and seed yield was highly significant positive indicating that pods per plant was the most important yield component in chickpea. It was also observed that the non-significant negative association between 100-seed weight and seed yield in F_3 became positive and significant in BIP population. Similarly, the non-significant positive association between secondary branches and 100-seed weight in F_3 became positive and significant in the BIP population. These results indicated that intermating in F_2 was quite effective in breaking undesirable linkages among traits.

Nagraj *et al.* (2002b) attempted biparental mating in the F_2 of ICCV 10 x BG 256 cross in chickpea. The biparental population (BIP) had batter mean performance than the F_3 self for the characters like plant height, primary branches, secondary branches, pods per plant, 100-seed weight and seed yield per plant. The lower limit of the range was, in general smaller for almost all the character in BIP. The upper limit had also increased in the desired directions for all the characters. Sufficiently high genetic variation was maintained in the BIP population for most of the characters, except secondary branches. BIP also exhibited improved estimates of heritability and genetic advance.

Two genotypes, L 550 (kabuli) and K 850 (desi) selected on the basis of their contrasting characters were used by Singh (2004) for the generation of genetic variability in chickpea. The results indicated that mean values for all the traits, except primary branches were higher in BIP than in F_3 progenies. The range of expression of lower limit was wider in biparental progenies and the upper limit of range was especially higher in BIP than in F_3 progenies for all the characters. At the same time the lower limit was lower in BIP compared with F_3 progenies for most of the traits, suggesting that intermating causes more variability than selfing. Estimates of variability, heritability and genetic advance showed that BIP progenies had greater genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and genetic advance for most of the characters. GCV and PCV were high for seed yield and pods per plant in BIP, indicating that there was a scope for selecting better segregants in the BIP population on the basis of pods per plant.

Jahagirdar *et al.* (2005) attempted biparental matting in the F_2 of BDN 9-3 x ICCV 2 cross in chickpea. The biparental population had batter mean performance than the selfed F_3 for the characters under study. Lower limit of the range was, in general, smaller for all the characters in the biparental populations. The upper limit was increased in positive direction for almost all the characters. High genetic variation was maintained in biparental populations, which also exhibited improved estimates of heritability and genetic advance.

Ravinder *et al.* (2006) evaluated two selection methods, i.e., visual selection (VS) and yield *per se.* selection(YPSS) by employing them on F_3 population of two chickpeas crosses, viz., cross-I (GSG 8962 X H 92-67) and cross-II (H 99-178 X ICC 11312) and growing selected F_4 progenies in next rabi season. Crosses I and II exhibited high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) in F_4 lines for fruiting branches per plant (FBPP), effective pods per plant (EPPP) and seed yield per plant (SYPP) in both selection methods. For 100-seed weight (SW), there was low GCV and PCV for both crosses in both selection methods. In cross I, YPSS method had higher heritability than VS method for FBPP and EPPP, while VS method was superior over YPSS method for SYPP and SW. The EPPP was the most heritable trait by both selection methods, followed by SYPP. In cross II, YPSS method had higher heritability than VS method for FBPP, EPPP, SYPP and SW. The EPPP and SYPP were the most heritable traits by both methods. In the both crosses, YPSS method had higher values for genetic advance under selection as percent of mean than VS method for FBPP, EPPP, SYPP and SW, except SW of cross I where the reverse was true. The SYPP had the maximum expected genetic gain in early generation selection for yield.

B. Other crops

Luedders *et al.* (1972) compared selection methods using soybean lines selected from populations advanced by the pedigree and early generation testing (F_4 and F_5) and 2 bulk methods (F_6 and F_7). Differences in the yield of these lines due to method of generation advance were not significant. However, with selection on 2-year means and in each individual year, the complete bulk (CB) and early generation testing (EGT) methods retained a few more lines than the maturity bulk (MB) and pedigree (P) methods. Methods of generation advance were highly significant for four character-population combinations but these appeared to occur at random except for seed quality-maturity in population 6. This association was not unexpected because seed quality and late maturity were significantly correlated in 14 out of 24 cases. Heritability estimates ranged from 10 to 40% for yield, 29 to 88% for height, and 23 to 72% for lodging.

Boerma and Cooper (1974a) studied F_2–derived heterogeneous soybean lines (HL) selected for high seed yield through early-generation yield-testing procedure (EGT) based on F_3, F_3–F_4, and F_3–F_4–F_5 combined generation means in four soybean crosses. Pure lines (PL) were selected for high seed yield from the same four crosses through pedigree selection (PS) and single-seed-descent (SSD) procedures. Selection of superior-yielding HL in the F_3, F_4, and F_5 generations decreased the coefficient of genetic variability in each generation of selection. The yield performance of the selected HL in the 1970 uniform preliminary test II also suggested that the HL were uniform among lines in yielding ability and the HL from one cross were equal in yield to the reference varieties. Further, results indicated that in one of the four crosses PL selected by the SSD procedure was significantly higher in yield and earlier in maturity than the

HL. In the other crosses, no significant yield differences existed between PL and HL, although the PL was usually earlier in maturity than the HL. These results suggested that pure lines from a cross will be equal to or higher in yield than F_2–derived heterogeneous lines.

Boerma and Cooper (1974b) selected lines from four segregating soybean populations through three selection procedure viz., early-generation yield testing (EGT), pedigree selection (PS), and single-seed-descent selection (SSD). In the F_8 generation of each cross the selected lines in each procedure were compared. The means of all selected lines, the means of the five highest-yielding lines, and the highest-yielding line from each population showed no consistent differences in procedures. The lines from the EGT procedure were consistently later in maturity than the lines from the other two procedures. This was attributed to the yield-testing in unbordered plots in the early generations by the EGT procedure. The SSD procedure emerged as the most efficient procedure, because it required less selection effort than the EGT and PS procedures, allows a rapid advance of the early-generation segregating populations, and did not use expensive yield-testing until later generations, when yield-testing is more efficient.

Inter-genotypic competition was studied by Khalifa and Qualset (1975) in populations developed from a hybrid of two wheat ‘D6301’ (short-statured) and ‘Ramona 50’ (standard-height). The F_2 through F_6 generations were grown in the field in two replicate subpopulations without artificial selection. Heights of individual plants, taken from the F_3, F_4, F_5, and F_6 bulk populations, were studied in the same environment. Mean height increased and frequency of short-statured plants decreased markedly from F_3 to F_6. Height of 62 random lines isolated from each of the F_2, F_4, and F_6 generations showed a decrease in phenotypic variance from F_2 to F_6. Grain yields of the F_2, F_4, and F_6 bulk populations and the means of 62 random lines (in F_3, F_5, and F_7) indicated a significant increase from the F_4 to F_6 and from the F_5 to F_7 generations. At F_7 the yield of the bulk population equaled the yield of the lower-yielding parent, Ramona 50. Variance in yield among lines increased from F_3 to F_7, but extremely short genotypes did not appear in the F_7. Extremely tall genotypes yielded less than those of intermediate height. Thus, in the bulk population directional and stabilizing selection affected both yield and plant height. Some lines in the F_7 had higher yields than either parent. Thus, in spite of natural selection against the agronomically desirable short plants, the bulk populations were useful as source materials in selection for increased grain yield.

O'Brien *et al.* (1978) studied the response to selection using four wheat crosses. Selection was based on the mean performance of F_3 lines (seed from a single F_2 plant) grown in three-row plot yield tests. Response to selection in each cross was measured using F_4 bulks, F_5 bulks, and the family mean of eight random F_5 lines. Significant response to selection was observed for Crosses I and II. These two crosses were characterized by wide yield range and a relatively high genetic variance among lines in the F_3 yield test. In Crosses III and IV, which were characterized by less yield range and genetic variance among lines in the F_3 yield test, response generally was not significant. The effectiveness of early generation yield testing was influenced by the amount of environmental variation among generation means and the amount of genotype and genotype x environmental variation. Realized heritabilities were lower than those estimated from testing at one location in a single year in all four crosses.

Two experiments were conducted by Gedge *et al.* (1978) to determine the overcompensation or under compensation due to inter-genotypic competition preferentially associated with high or low-yielding heterogeneous soybean lines. In Experiment 1, yield of 40 random F_2-derived lines, four F_5-derived lines from each F_2 line, and a blend of the four F_5 lines (F_5 blend) of two crosses were evaluated. Linear regression was used to compare the yield of the F_2 lines and F_5 blends with the mean yield of the four F_5 lines. In Experiment 2, four F_5-derived lines were selected from each of six high and six low-yielding F_2-derived lines in the two crosses. The four F_5 lines were evaluated for yield in pure stands, in the six possible two-component blends, and in a four-component blend. Yields of the blends were compared with average performance of the components in pure stands. In both the experiments, overcompensation and under compensation was not preferentially associated with high or low-yielding heterogeneous lines. The results indicated that early generation testing for yield in soybeans should not be biased significantly by inter-genotypic competition within heterogeneous lines.

Whan *et al.* (1981) studied the relationships between the F_2, F_3, F_4 and F_5 generations for grain yield using random and pedigreed lines derived from each generation. The lines from two crosses were grown in plots at two sites over two years. In the first year, only F_2 and F_3 derived lines were available, but in the second year the F_2 to F_5 were grown. Correlations between lines in one generation and the mean of lines derived from them in a following generation increased as the generations were advanced. Correlations between consecutive generations were higher than those between generations two or three apart. Correlations between F_2 and F_5 derived lines, which indicate the effectiveness of selecting F_2 lines, varied from 0.10 ns to o.49** when lines from both generations were grown in the same environment. Correlations between years of lines from the same or different generations were low and often non-significant. Harvest index was measured on the F_2 and F_3 derived lines at the one site in the first year. Selection for improvement of grain yield using harvest index was no more effective than selection for yield directly, when considered across years. It is concluded that, while gains in 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.

Ahn *et al.* (1982) studied effectiveness of early generation selection using F_2 individuals and F_4 lines in wheat. Correlation analysis between F_2 individual and F_3 lines indicated that the plant height, heading date and winter hardiness may be improved through early generation selection and with remarkable genetic advances by selection. Early generation selection for yield potential varied depending upon the cross combination tested, but, generally speaking, correlation coefficients estimated between F_2 and F_3 generation, heritabilities and genetic advances were low enough to conclude that its selection would be negligible effective in early generation.

Whan *et al.* (1982) studied simulating selection response for grain and harvest index in wheat using F_2, F_3, F_4

and F_5 derived lines from two crosses grown at two sites over two years. Improvement in yield through selection was obtained when the response was measured at the same site and in the same year as the selection. Selecting the best 10 per cent of F_2 to F_4 derived lines gave F_5 derived lines that out yielded random selections by 19 to 53 per cent for one cross and 5 to 23 per cent for the second cross. These lines were 41 to 50 per cent better than the mid-parent in one cross, but were less than the mid-parent in the other cross. However, the response to selection when measured in a different year was little better than random selection. The effect of different sites also reduced the effectiveness of selection. Selection of harvest index in early generations for improvement of yield was ineffective when response was measured at the same site in the same year, or in different years. Contrary to some theoretical proposals, the same improvement in yield was obtained by selecting in early or late generations. While high yielding genotypes may be lost by delaying selection, this may be counteracted by the better predictive value of late generations due to their greater homozygosity and homogeneity.

The objectives of study by Ntare *et al.* (1984) was to evaluate early generation selection procedures for their effectiveness in isolating high yielding lines of cowpea and to ascertain the relationship between yield performance in early (F_3) generation and later generations (F_5 and F_8). Four selection procedures viz., single plant selection (SPS), single plant bulk (SPB), bulk single plant (BSP) and selected bulk (SB) were used based on F_3 yield evaluation. Lines arising from these procedures in six crosses were compared in F_8 for yield performance. Unselected lines were used as control. The differences among the four selection procedures with respect to grain yield were not significant. However, the most high-yielding lines were from the SPS procedure. The SB procedure gave the lowest number of high-yielding lines but required the least amount of land. The mean yields of F_3 lines and bulks and the yields of F_5 and F_8 derived lines were significantly correlated, (r = 0.64**and r = 0.70**).

Dahiya and Singh (1986) applied three selection methods viz., single seed descent (SSD), mass selection and selective intermating simultaneously to a highly heterogeneous and broad based population of green gram. Progeny developed after two cycles of selection were evaluated for yield and seven other economic characters. The relative efficacy of each selection method was judged on the basis of the number of high yielding progeny, mean yield of top 10% progeny, and mean of the highest yielding progeny. Selection after two cycles of selective intermating was found to be the best method for generating productive progeny although mass selection favouring smaller seeds was an equally efficient method. Both of these were found superior to SSD selection.

A study by Sharma and Smith (1986) was undertaken to estimate the heritability of harvest index and to determine the response to selection for high and low HI in three genetically diverse populations of winter wheat. Selections were made in the F_3 generation and selected progenies were evaluated in replicated tests in the F_4 generation. Realized heritability estimates for HI were intermediate in magnitude (0.44 to 0.60). Selection in F_3 for high and low HI was effective in identifying F_4 lines with high and low HI, respectively. Also, selection for high HI resulted in shorter plants with earlier heading dates and lower biomass yield. Genotypic correlations between HI and grain yield were low (r_g = 0.04 to 0.23). Phenotypic correlations between HI and grain yield were relatively high in the F_3 but much lower in the F_4. Harvest index was negatively correlated with plant height and days to heading, while correlations between HI and biomass yield were mostly non-significant. Simple correlation coefficients between F_3 and F_4 means were higher for HI than for grain yield. This indicated that HI in the F_3 generation was a good predictor of HI in the F_4, but a poor predictor of grain yield in the F_4.

Wong and Baker (1986) studied effectiveness of selection for time to maturity and 11 other traits in 50 F_2-derived

F_3; lines in each of six wheat crosses growing under dry land and irrigated conditions. High heritabilities and high genotypic correlations with time to maturity indicated that time to full flag-leaf emergence, times to beginning or completion of spike emergence, time to anthesis, spike moisture and number of leaves could be used as selection criteria for time to maturity. Bidirectional selection for time to maturity (10% selection intensity) showed that selection was more effective in some crosses than in others. Realized heritability for time to maturity varied from −8 ± 21% to 186 ± 50% depending on cross and environment. Bidirectional selection for number of leaves (6% selection intensity) confirmed that this character is a reliable criterion for altering time to maturity. With selection differentials of 0.95 to 2.64 leaves, correlated response for time to maturity varied from 40 to 119 growing degree-days. Number of leaves and spike moisture concentration are useful methods for evaluating maturity when developmental stages cannot be measured at frequent intervals.

A study was carried out by Quail *et al.* (1989) using F_3 single plant comprising 220 F_1-derived lines taken at random from a multiple convergent cross amongst 16 parents representing elite CIMMYT germplasm of wheat for more than 50 traits comprising numerical components of yield, size and morphology, partitioning ratios, development rates and physiological activities. All F_3 traits showed significant genotypic variation which was usually greater for progeny lines than for parents although only occasionally significant. Broad sense heritability was generally moderate to high. F_3 lines were advanced by single seed descent for replicated F_7 and F_8 yield experiments. Yield levels were high (mean yield 5.9 t ha^1 at 10% moisture) and largely free of interference from lodging and disease. The progeny main effect on grain yield was highly significant, but no progeny line significantly out yielded the best parent. Best correlations with progeny grain yield were given by F_3 plant height (r= -0.31 to -0.50 across experiments), F_3 kernel weight (r= -0.03 to -0.44), F_3 harvest index (r = 0.18 to 0.5 l), F_3 leaf angle (r = -0.13 to -0.40, erect leaves favoring high yield) and F_3 spike number (r=0.08 to 0.40). Retrospective selection in F_3 using these traits singly at a selection intensity of 25% gave increase in population mean yield (0 to + 12%) and in the proportion of high yielding lines (doubled in some cases), but only selection in F_3 for reduced stature was considered worthwhile for advancing yield potential. It was suggested that the ineffectiveness of F_3 selection is largely due to genotype by environment interaction, along with the complex multigenic nature of grain yield.

Experiments on early segregating generations of a selected narrow-leaf lupin cross were conducted by Thurling and

Ratinam (1989) to determine the effectiveness of selection based on seed yield and several other yield-related characters. Randomly selected plants from each population were grown over the summer (off-season) in a glasshouse to generate F_4 populations. Analyses of relationships between F_2 plant measurements and F_3 progeny mean yields revealed significant correlations only for those characters with high heritability - flowering time, 100 seed weight and harvest index. However, selection for the earliest flowering F_2 plants followed by selection within this group of plants with the highest number of pod bearing branches would result in the greatest increase in F_3 mean yield. The F_2-derived F_4 populations with the highest seed yields were those obtained by selection for total plant dry weight, number of pod bearing branches and number of pods per plant. Improvement in commercial crop yield should therefore be obtained through selection in early generations for those characters contributing to the greatest number of pods per unit area. A scheme involving selection for early flowering and high number of pod bearing branches in the F_2 combined with replicated yield tests in the F_4 was proposed.

Early generations testing for resistance to early and late leaf spot in peanut was carried out by Anderson *et al.* (1990) through obtaining heritability estimates, responses to selection and relationship of resistance in two peanut populations.

Selection based on F_2 family means in the F_3 generation *via* defoliation, infection, and sporulation was performed. Divergent selections for each disease were evaluated in the F_4 generation at the same locations in the following year for resistance by visual rating of infection and defoliation. Narrow-sense heritability estimates from parent-offspring regression (0.18–0.74) and realized heritability (0.60–1.41) were significant for late leaf spot resistance and early leaf spot resistance in the PI 314817/[TG3/EC 76446 (292)] population. Results indicated that selection based family means would be successful. Selection of individual plants within families did not significantly improve genetic progress. Moderate to high correlations (0.41–0.86) existed between early and late leaf spot disease components indicating possible genetic linkage or host-plant physiology that conferred resistance to both diseases in one population.

Areerat (1990) carried out early generation selection procedures for their effectiveness in isolating high-yielding lines and ascertain the relationship between yield performance in early generation (F_3) and later generation (F_4 and F_5) in three sesame crosses. Two selection procedures viz pedigree selection (PS) and bulk selection (BS) were used. F_2 plants were selected and seeds were divided into two groups. The first group used for PS and the latter used for BS. F_3 yield trial was conducted using systemic controls. Lines were obtained from PS procedure in the F_4

generation whereas bulk populations were obtained from BS procedure from F_4 and F_5 derived lines. PS and BS procedures could be used in early generation selection for yield in sesame. However, BS appeared to be more efficient than PS because lower utilization of land, labour and expense. BS could be used until F_5 generation and then individual plant selection could be done. Because of high correlation of number of capsules per plant with seed yield, this character could be used as indirect selection for high-yielding lines.

Efficiency of selection was studied by Stelling and Ebmeyer (1990) for yield and yield related characters in the F_3 based on F_2 derived single plant progenies of four pea crosses. Early yield selection in the F_2 as well as in the F_3 proved to be of poor efficiency. Heritability values of all recorded traits were only slightly higher in the F_3 than in the F_2. Efficiency of yield selection could not be increased significantly in these early generations by indirect selection, either for single trait or for index trait. Possible reasons have been discussed for the low efficiency of direct and indirect selection for grain yield in early generations and suggested the alternative selection strategies for its improvement.

Hucl and Baker (1991) studied effectiveness of selection for tillering capacity in wheat crosses derived from high tillering ('Neepawa', 'Ingal'), low tillering ('Ko Fong', 'Siete Cerros'), and oligoculm (M1417) parents. The F_1, F_2, and the F_2-derived F_3, F_4, F_5, and F_6 lines were tested under dryland conditions. The 10 highest- and 10 lowest-tillering F_7 lines from each of the oligoculm crosses were grown under irrigation condition. Heritability estimates for tillers per plant were, on average, much higher for the oligoculm crosses. At commercial seeding rates, high- and low-tillering F_4 lines differed significantly in spikes per square meter in eight out of nine populations. High- and low-tillering selections in oligoculm F_4 populations differed, on average, by 19% for spikes per square meter, compared with 12% in nonoligoculm crosses. Averaged across two year, the low-tillering selection group in oligoculm crosses yielded 7% less than the high-tillering group. Early-generation divergent selection for tillering capacity was more effective in oligoculm than in nonoligoculm crosses.

Selection for yield in early generations was studied by Peters *et al.* (1991) in wheat. The F_3-derived progenies, corresponding to poor and good yielding bulks in F_4 were selected. In later generations the average yield of the group of strains with good yield in the F_4 was 4 % (F_5) and 3 % (F_6) higher, respectively, than the mean of the strains with low yield in the F_4. Strains with very low yielding potential can easily be discarded in the F_4. The risk of discarding lines with a very high yield is minimal. Selection for yield in the F_4 was as effective as in the F_5. The importance of testing F_2-derived bulks in the F_4 is not only based on the assessment of yield but also on the possibility of reliable intensive selection through recording visual characters (height, resistance against diseases) in a second environment in parallel to the single plant progenies.

Rana and Gupta (1993) studied F_3, F_4 and F_5 generations of the plants selected from F_2 and F_3 generations of pea cross HPPC 63 X Lincoln and calculated response to selection and realized heritability increased in the successive generations. The plants selected in F_2 generation did not show any correlation with their progenies in F_3 and F_4 generations for all the traits except resistance to powdery mildew disease which showed consistency in subsequent generations also. However, the plants selected in F_3 generation showed positive correlation with their progenies in F_4 and F_5 generations for seed yield, pods per plant, l00-seed weight, harvest index, and reaction to powdery mildew. Maximum response was observed in F_5 generation when selection was practiced in F_3 generation. The study, therefore, revealed that selection for polygenic traits like seed yield should preferably be done after F_2 generation. However, selection for monogenic or oligogenic traits like resistance to powdery mildew can be practiced in F_2 generation itself.

Sharma (1994) studied early generation selection for long and short grain-filling period (GFP) in six genetically diverse populations of spring wheat. Selections were made in the F_2 generation and selected progenies were evaluated in the F_3 generation under normal and late conditions. Date of seeding had a significant effect on GFP, grain and biomass yield, harvest index, and hundred kernel weight. Selection in the F_2 for long and short GFP was effective in identifying F_3 lines with long and short GFP, respectively. Also, selection for long GFP usually resulted in higher grain and biomass yield. Average harvest index and hundred kernel weight of the long GFP lines were higher than those of the short GFP lines. Realized heritability estimates for GFP were intermediate to high in magnitude (0.52-0.86). Duration of GFP had a high positive genotypic correlation with grain yield (0.52-0.79), harvest index (0.50-0.80), and hundred kernel weight (0.53-0.72). Results indicated that selection for long GFP in early segregating generations should bring about positive improvements in these yield components.

The information on early generation selection for fruit yield in egg plant was derived by Narendra Kumar and Ram (1995) using three generations (F_2, F_3 and F_4) from the crosses of 4 varieties. The mean fruit number of F_3 progenies derived from selected F_2 plants was significantly higher than that of those derived from random F_2 plants in 2 out of 4 crosses. In the F_4, mean of selected progenies was significantly better than mean of random progenies in all crosses. Selected plant progenies performed better than random ones in F_3 and F_4 generations in all crosses for yield/plant. Selection was effective in raising the mean of progenies derived from selected plants and also in terms of increased number of superior lines occurring in the selected group.

Singh and Singh (1997) tested reliability of individual plant selection for grain yield, plant height, effective tillers, total dry matter, grain per spike, kernel weight and harvest index in five F_2 populations of bread wheat. Plants were selected for each of the seven characters in positive and negative directions in F_2 generation and selection response was measured in F_3 generation. Intergeneration correlation coefficients and realized heritability estimates were also computed for all the seven characters in the five F_2's. Individual plant selection for plant height and for kernel weight was found to be effective while, it was ineffective grain yield, number of effective tiller, total dry matter, grains per spike and harvest index.

Borghi *et al.* (1998) measured the response to selection for grain yield (GY) and harvest index (HI) applied in different generations from F_2 to F_6 in nine segregating populations of bread wheat previously screened in F_2 by means of visual selection. Genetic variability for HI and GY was found in most of the segregating populations. However, GY of spaced plants in F_6 and F_3 generations was weakly correlated with yield of F_4 and successive generations grown at normal seed density. HI was of limited value as an indicator of yield potential.

Mitra and Mehra (1998) compared three selection methods using the F_2 populations of 2 crosses of grass pea by advancing through single seed descent, random bulk and pedigree methods up to F_5 generation. The F_5 populations of these crosses were evaluated for comparing the relative efficiency of these 3 breeding methods in obtaining transgressive segregants for yield and its components. The single seed descent method proved to be superior to random bulk and pedigree methods in producing greater frequency of transgressive segregants in F_5 generation for yield and its components, whereas the random bulk method showed a poor performance in this regard.

Lu *et al.* (1999) computed the variability using breeding lines from the F_2, F_3, and F_4 generations and the parental varieties of 4 barley crosses growing in two seasons. Both malting quality and grain yield greatly influenced by environment and exhibited a wide range among progenies in all generations. Performance in one environment was predictive of that in other environments. Heritability was generally higher for F_3 to F_4 than for F_2 to F_3 for all malting quality attributes. F_3 on F_2 regression percent heritability estimates for protein content, potential malt extract and grain weight were highly significant with values generally medium in magnitude. Heritability and genetic gain varied from cross to cross. Heritability for F_2 to F_3 for grain yield was not significant in any cross; indicating selection for yield on the basis of individual F_2 plant yield was ineffective. Heritability for grain yield from F_3 to F_4 was highly significant and medium in magnitude for 3 of the 4 crosses. The results indicate that good genetic gain could be expected from early generation selection for potential malting quality and for grain yield in later generation using F_3 progeny testing.

Vir Om and Gupta (1999) evaluated lentil F_2 derived lines (160) in F_4 of four macrospenna x microspenna crosses, selected on the basis of high seed yield per plant (g), and high harvest index in the background of bold seed size from 713 F_2· derived lines in F_3 evaluated in an augmented randomized block design under two nitrogenous regimes Le., 20 kg N/ha (E-I) and 40 kg N/ha (E-ll). Estimates of correlation coefficients of selected F_2 derived lines in F_3 with the corresponding lines in F_4 were highly significant and positive with respect to seed yield/plant (0.91 and 0.92 in E-I and E-ll, respectively), biological yield/plant (0.75 and 0.72 in E-I and E-ll, respectively) and 1OO-seed weight

(0.91 and 0.92 in E-I and E-ll, respectively). At 5% selection intensity, standardized selection differential was observed to be the highest for all studied traits followed by 10% and 22.5% selection intensities. Standardized response to selection at 5% selection intensity was estimated to be the highest for all traits in E-ll and it was equally good in E-I also. However, E-ll was observed to be superior for all the traits for estimation of response to selection at different selection intensities. The realized heritability of seed yield per plant was estimated to be high at 5%, 10% and 15% selection intensities in E-II. For 100-seed weight the estimated realized heritability was high in all cases. The present result favours the view that most desirable gene combinations can be identified even in the heterozygote.

Mehta (2000) compared five breeding procedures, viz., pedigree selection for early flowering (PS (EF)), pedigree selection for high yield (PS (HY)), mass selection (MS), single seed descent (SSD) and random bulk (RB) employing in the F_2 and compared in segregating F_3 and F_4 generations of four cowpea crosses. PS (HY) scheme of F_3 recorded the highest pods/plant and seed yield/plant in all the crosses except GC 2 x V 240, while in F_4 generation, significantly higher number of pods/plant were obtained in PS (EF) in the crosses of Pusa phalguni x V 269 and GC 2 x V 16 and it was at par with PS (HY) in rest of the crosses. However, quite different results were obtained for seed yield/plant in F_4 generation. The widest phenotypic range and higher variances were exhibited by MS for pods/plant and seed yield/plant in all the four crosses in both generations. PS (EF) and PS (HY) exhibited uniformly low CV in all the four crosses for both the traits in both generations and it was in general consistent over generations in comparison to higher CV of SSD, MS and RB schemes. The shift towards early flowering and maturity in F_3 and F_4 was caused by PS (EF) in all the crosses except one cross in both generations for days to maturity.

Jayalakshmi *et al.* (2000) carried out early generation bulk yield test for predicting the yield potential in later generations by evaluating F_1, F_2 and F_3 generation of 21 groundnut crosses during the post-rainy and rainy season. Positive and significant correlations between kernel yields of bulk F_1 vs. F_2 and F_2 vs. F_3 generations indicated that yield test of an early generation bulk of groundnuts can be used for identification of potential crosses in early generations. The relative ranking of crosses either in F_1 and F_2 (or) F_2 and F_3 (or) both tests was found to be a suitable index to decide whether a cross should be pursued or discarded in early generations.

Santos *et al.* (2001) studied effect of early (F_2 generation) selection for grain type on grain yield in a cross of common bean (*Phaseolus vulgaris*). The F_2 harvested seeds were divided into two groups, one with "carioca" grains and another of mixed type, where no selection was applied. The F_3 plants of both sub-populations were individually harvested resulting in 199 families per sub-populations. The $F_{3:4}$ and $F_{3:5}$ families were assessed during subsequent year. On average, no yield differences among the non-selected and selected for grain type family means were detected. It was also observed that the heritability estimates were high and similar. It is, therefore, inferred that early (F_2 generation) selection for grain type did not reduce the potential of the population for selection of superior inbred lines. Consequently, strong selection for grain colour in the F_2 generation, to screen out undesirable types will enable breeders to concentrate their efforts on the selection of other traits in the advanced generations. Only families with commercially acceptable grain type should be subjected to selection for increasing the chances of success.

Two selection procedures, viz., wheat grain yield (GY) and total dry matter (TDM) was studied by Mahesh and Khedar (2001) in 2 wheat crosses (Raj. 1555 x NI 7444, POW-215 x HO4530). At maturity, 80 F_2 plants having good agronomic characteristics were harvested from each cross and evaluated for GY, TDM and grain protein. The top 20% of the F_2 plants in GY and in TDM from each of the crosses were tagged and their performance monitored together with the rest of the lines in F_3

and F_4 bulk yield tests. The grain yield selection procedure identified 7 F_3 and 7 F_4 high yielding bulks while the TDM selection procedure identified 13 F_3 and 10 F_4 high yielding bulks from the 2 crosses, indicating that TDM selection procedure was superior to the GY selection procedure in identifying F_2 single plants having high yield potential.

Inheritance of morphine in opium poppy was studied by Shukla and Singh (2001) by selfing and selecting for high, low and intermediate morphine content in seven successive generations. The morphine content over years ranged from 7.14 to 29.98 percent. Progenies with high morphine content segregated strongly and produced progenies with lower content, while selection in middle order produced high and intermediate progenies. Selection response was also high in progenies selected from middle range. The results suggest that high morphine content resulted due to certain epistatic combinations.

Kishor and Gupta (2002) evaluated 475 recombinant lines of 26 crosses in F_3 generation and 409 recombinant lines of 24 crosses in F_4 generation derived from crosses involving *microsperma* and *macrosperma* groups of lentil, raised in augmented design, revealed sufficient genetic variability for seed yield per plant, biological yield per plant, 100-seed weight, harvest index, seeds per pod, days to 50 % flowering and days to maturity. Biological yield per plant and seed yield per plant showed high degree of PCV, GCV and genetic advance. Heritability was high for biological yield per plant and days to maturity whereas, moderate for seed yield per plant and most of the traits. Seed yield per plant showed significant positive association with biological yield per plant, harvest index, seeds per pod, 100-seed weight and days to 50% flowering in both F_3 and F_4 generations in almost all the crosses of different groups. Crosses involving Precoz and PL-639 as one of the parents were promising. Crosses L-4145 x PL-639, Precoz x PL-639, Vipasha x PL-639 and Precoz x L-259 were with higher transgressive segregations. About 15% (123) and 10% (92) of the progenies gave higher yield over the better parent and the best check, respectively. Seven per cent (55) bold seeded progenies were identified in the population with nine progenies having both high yield and bold seeded.

Vanina Cravero *et al.* (2002) evaluated 32 half-sib families obtained from selected plants of three populations of the *asparagus* variety Argenteüil. The values of realized heritability were estimated and were compared with those obtained by the parent-offspring regression method. Phenotypic correlation coefficients between the different variables were significant. The values of realized heritability for most of the variables were moderate to high (between 0.18 and 0.68), except for days to emergence; lower values were obtained by the regression method. As there was a high degree of heritability, additive genetic factors contributed significantly to the genetic variance, which could allow the selection of phenotypically superior plants for *asparagus* improvement.

The relative effectiveness of the various selection criteria was examined by Singh and Balyan (2003) from three F_2 populations of wheat. The criteria considered were: (i) selection for high as well as low values of seven individual plant traits (grain yield *per se*, plant height, grains per spike, 100 grain weight, tiller number, biological yield and harvest index), (ii) selection of single plants based on an index involving greater values of the above seven traits than their means of the population, and (iii) random selection, in association with and without yield testing in the F_5 generation. The selection pattern of the parent F_2 plant(s) of each of the ten highest yielding F_5 selected F_4 bulk progenies and F_4 bulk progenies revealed that (i) selection of plants in F_2 populations on the basis of a single trait was relatively more effective than selection at random while selection based on the index was ineffective, (ii) selection of plants with higher expression of trait(s) resulted into 75% of the highest yielding F_4 bulk progenies, (iii) selection of individual plants in F_2 generation based on biological yield followed by grain yield *per se* proved most effective, and (iv) the yield testing in F_5 generation was only moderately efficient in identification of high yielding F_4 bulk progenies.

Rex Bernardo (2003) examined the theoretical effectiveness of early generation selection with the assumption that when dominance is absent, the genetic correlation (*r* G) between the performance of an Ft–derived Fg line (i.e., Ft:g) and a descendant homozygous line is equal to the square root of [1 + *F* (t)]/2, where *F* (t) is the inbreeding coefficient at generation *t.* Dominance, when present, has little effect on *r* G. The minimum value of *r* G is high; that is, 0.707 for an F_2–derived line. From a genetic standpoint, early generation selection is expected to be effective, but in practice it becomes ineffective if nongenetic effects are large. Early generation selection in self-pollinated crops typically involves the evaluation of F_2– or F_3–derived lines from the cross between two inbreds. Inferior F_2– or F_3–derived lines are then discarded to allow the expenditure of resources on the testing and selection of the more promising lines. The F_2– or F_3–derived lines are far from being homozygous, and early generation selection relies on the assumption that the performance of a line at an early generation of selfing is predictive of its performance at homozygosity.

Intergeneration correlation studies (F_2F_3, F_2F_4 and F_3F_4) conducted by Bhagowati and Hazarika (2004) in three black gram crosses for seven yield attributes, indicated the gross ineffectiveness of early selection in black gram. Differential segregation and recombination in early segregating generations, together with higher genotype x environment interactions might be the probable reasons for this ineffectiveness. The heritability estimates indicated the ineffectiveness of early selection as groups (positive and negative) for three characters i.e., plant height, pod number and grain yield per plant. However, for harvest index, the estimate was fairly high, indicating its suitability as a selection criterion.

Naidu *et al.* (2004) assessed their material for examining response to selection for dormancy and suggesting a breeding strategy for selecting dormant segregants in Spanish groundnut. The results revealed that selection in segregating generations at advanced generation was more effective than either early generation selection or continued selection. Continuous selection at all stages resulted in the elimination of potential segregants for pod yield combining dormancy. A simple strategy of breeding for dormancy could be crossing of dormant donors with adapted non-dormant cultivars, advancing segregating material either through bulk or single seed descent, evaluating single plant for dormancy at F_4 seed level and eventually testing for pod yield in replicated trials in later generations.

Singh *et al.* (2005) studied the response of selection for main shoot length, seeds per siliqua, seed mass and seed yield in F_2 generation of three Indian mustard crosses. Five plants with high and five with low values were selected for each trait. On the other hand, a bulk was constituted by taking one seed from each plant in each cross. These selected plants as well as the constructed bulks were raised to advance from F_3 to F_4 generation. In F_5 generation, it was observed that differences between high and low selection were non-significant for all the traits except seed mass. On the other hand, mean values under bulk were comparable to that of high selection group for each trait. Bulk was advised to be followed in early generation. The change in relationship between seed mass and seeds per siliqua from F_2 to F_5 turned to be negative.

Vir Om and Singh (2005) evaluated one hundred and fifty seven F_4 progenies from three Basmati x non-Basmati rice crosses, selected on the basis of high yield/plant and harvest index in the genetic background of fine grain quality characteristics from 498 F_3 progenies evaluating under two environments i.e. 120 kg N/ha (E-I) and 160 kg N/ha (E-II). Estimates of correlation coefficients between selected F_3 progenies and corresponding F_4 lines were highly significant and positive with respect to grain yield per plant, biological yield per plant and 1000-seed weight. At lowest selection intensity, standardized selection differential was the highest for all traits. Standardized response to selection at such low selection intensity was the highest for all traits in E-II and equally good in E-I. Realized heritability for grain yield per plant was high at 5%, 10% and 15% selection intensities in E-II. For 1000-grain weight the estimated realized heritability was high in all cases.

The effects of retrospective selection on grain yield and other agronomic characteristics in advanced families of cowpea were examined by Padi and Ehlers (2007). A set of 131 F_5 generation lines derived from bulked $F_{2:4}$ lines developed from a cross with mild selection in the F_2 to F_4 generation were grown in three locations. Genotypic correlation for grain yield between locations was high only between the two locations. Heritability estimates based on F_3-F_5 correlations were lower and not different from zero for grain yield, but heritability estimates for days to flowering and seed size were higher. Based on the lack of significant difference between the F_5 mean grain yield of F_3 selected and rejected groups, and the low recovery of the 10% top yielding lines in the unselected population at each of three locations, early generation selection for grain yield was deemed ineffective. They suggested single seed descent approach for developing cowpea lines with high yield potential.

Siddhu *et al.* (2007) studied F_3 and F_4 generations of two inter specific crosses of soybean viz., (PK 472 x Glycine soja) x PK 472 and (Bragg x Glycine soja) x Bragg for yield improvement. Twenty top ranking plants, out of 200 visually selected plants from F_3 generation each for number of pods per plant and dry matter yield were independently evaluated in F_4 generation from both the crosses. Mean of the selected progenies for dry matter (88.45 and 82.58 g) and for pods per plant (255 and 200) were higher as compared to the bulk (77.6 and 60.59 g) and (194 and 172) in respective crosses. Selected progenies for dry matter and pods per plant selection showed 15.18 and 45.17 per cent yield superiority in (PK 472 x Glycine soja) x PK 472 whereas, in second 36.31 and 45.65 per cent in second cross, respectively. Both the yield components showed significant positive correlation with seed yield. High broad sense heritability and high genetic advance was also observed for number of pods per plant, dry matter and for their respective yield in the selected progenies in both the crosses. Proportions of significantly superior progenies over the better parents were also substantially higher in selected progenies as compared to respective bulks.

Agnaldo *et al.* (2008) studied genetic parameters and breeding values in $F_{2:3}$ and $F_{4:5}$ progenies and the $F_{2:4}$ and $F_{4:6}$ generations derived thereof of soybean. These progenies were originated from two semi-early lines that differ in grain yield. The trait grain yield per plot was evaluated. It was observed that early selection was more efficient for the discrimination of the best lines from the F_4 generation onwards.

Padi (2008) studied correlated response to selection in large grain size and earliness to flowering in the two cowpea populations in which selections were made primarily for grain yield potential. Each of the two populations, SARC 2 and SARC 3, was derived from a cross between an adapted parent Marfo-Tuya and an exotic breeding line that has large grain size and early flowering. Replicated yield evaluation of F_5 families showed that grain yield of Marfo-Tuya was not different from those of the highest yielding families in each population. Increase in grain size of individual families over Marfo-Tuya was large and, the response to selection averaged 5.3 and 3.9 g/100 seeds in the SARC 2 and SARC 3 populations, respectively. Response to selection in days to flowering averaged 3 days in SARC 3, whereas response to selection was not observed in SARC 2. Retrospective selection in the F_3 at 40% intensity was efficient in identifying a high proportion of elite families in each population.

An effectiveness of early generation selection for seed yield was examined by Padi and Ehlers (2008) in cowpea population of 131 $F_{3:4}$ lines developed from a cross between a local cultivar and an unadapted source of large grain size. Mild selection was practiced during line development and unreplicated F_3 plant data were collected on all the lines. Multilocation trials were conducted with lines formed by bulk harvest of F_4 families to assess how effectively the early generation selection protocol was able to generate superior lines for the target agroecology. Genotypic correlation for grain yield between locations was high. Narrow-sense heritability estimates were low and not different from zero for grain yield, but heritability estimates for days to flowering and seed size were large. F_4 lines derived from the highest 10% performing F_3 individuals were no higher yielding than F_4 lines derived from the remaining F_3 individuals, indicating that early generation selection for yield was ineffective. He suggested that single-seed descent (SSD) or bulk breeding methods will be more efficient than pedigree breeding for developing cowpea varieties with high yield potential for this agroecology.

Early generation selection was carried out by Shiv Kumar *et al.* (2008) using different methods of selection in segregating generations of five wheat crosses and a comparative effectiveness of selection methods was worked out. Observations were recorded in three generations for days to heading, days to maturity, plant height, number of tillers per plant, ear length, number of spikelets per ear, number of grains per ear, grain weight per ear, 100-grain weight, biological yield per plant, grain yield per plant and harvest index. The single ear selection method was the most effective, followed by the 1% selection intensity, 2% selection intensity, random sampling and bulk sampling methods.

In his early generation testing study in soybean, Carvalho *et al.* (2009) generated population deriving from a two-way cross between lines 14 and 38, divergent for grain yield. One hundred progenies $F_{2:4}$ and one hundred progenies $F_{4:6}$ derived from this population were evaluated at two locations. The components of variance, coefficients of heritability and expected response to selection were estimated for grain yield from the joint analysis of variance for $F_{2:4}$ and $F_{4:6}$ generations. Estimates of expected response to selection were about 60% higher in the $F_{4:6}$ generation; however this superiority would probably be offset by the larger time to complete a cycle. General results indicate that early generation testing for grain yield in soybeans can be effective for moderate selection intensities.

Isaía and Maich (2009) calculated realized heritability for several traits of a selection index applied in rainfed bread wheat and hexaploid triticale. S_0 progenies selected disruptively and evaluated as S_1 derived families. The selection differential (SD) and the response to selection (RS) were estimated from the S_0 progenies and the S_1 derived families, respectively, as the differences (in percent) between high and low (=100) selection index group mean values. In bread wheat, significant differences between groups of S_1 derived families were observed in the 7th cycle for all the studied traits; while only significant differences for harvest index were observed in the 8th cycle. Taking into account only the statistically significant differences between high and low selection index group mean values, the realized heritability estimates for grain yield, biomass yield and grain number were lower (7.0% to 11.2%) than those obtained for 1000-grain weight and harvest index (12.3% to 20.5%). The narrow germplasm base in triticale generated nonsignificant response to selection results.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation on "Early generation selection for yield and its components in Chickpea (*Cicer arietinum* L.)" was conducted at the Instructional Farm, Junagadh agricultural University, Junagadh during *Rabi* 2006 (F_2) and 2007 (F_3). Junagadh is situated at 21.5 ^{0}E latitude and 70.58 ^{0}E longitude with an elevation of 82.92 meter above the mean sea level.

3.1 EXPERIMENTAL MATERIAL

The experimental material consisted of F_2 generation for *rabi*-06 and F_3 generation for *rabi*-07 of five crosses involving seven parents. The parents and F_2 seeds were received from the Research Scientist (chickpea), Pulses Research Station, JAU, Junagadh. The crosses used in the present study were, 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), hereafter referred to as Cross 1, Cross 2, Cross 3, Cross 4 and Cross 5, respectively. The parents involved in various crosses are listed with their pedigree and origin in Table 3.1.

3.2 EXPERIMENTAL DETAILS

Five F_2 populations and seven parental lines were sown during *Rabi* - 2006 in a randomized block design with three replications under irrigated condition. Five rows of four meter length spaced at 45 X 10 cm distance were allotted to each F_2 population, while single row of same length and spacing was allotted to each parent. The guard rows were provided surround the experimental area to avoid damage and border effects.

At maturity, data were collected on randomly selected seventy-five plants from each of the F_2 generations and five plants from each of the parental lines per replication. After harvest and evaluation of the data, high and low groups were generated from populations of each cross by selecting the ten highest and the ten lowest entries 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. A total of 226 selected plant progenies were grown for F_3 field trial in randomized block design with three replications during *Rabi*-2007. Plot was of single row of 1.5 m length for each F_3 line keeping spacing of 45 cm between the rows and 10 cm between the plants within row. Row length (1.5 m) was decided based on seed availability of selected F_2 plants. During studies of both generations i.e. F_2 and F_3, soil of experimental area was fertilized at the rate of 25 kg N and 50 kg P_2O_5 per hectare.

Pre-emergence application of pendimethaline @ 0.5 kg/ha and interculturing during first 4-6 weeks was done to keep the crop weed free. The crop was irrigated at 45 days after sowing and at early pod filling stage. Insecticide like Endosulfan (0.07%) was sprayed at the pod formation stage to control pod borer. Whereas, soil drenching with chloronob (20 kg/ha) was carried out for controlling collar rot disease.

Table 3.1: Pedigree and Origin of parents used in the study

Sr. No.	Name of parent	Pedigree	Source of origin
1	GJG 9905	(H 86-142 X ICCV 10 X ICCV 89344)	Junagadh
2	Vishal	---- --	Maharashtra
3	CSJ 103	RSG 44 X PDG 84-10	Durgapur
4	JCP 27	JG 71 X P 380	Junagadh
5	GJG 0106	ICCV 93001 X ICCV 10	Junagadh
6	Phule G 96006	---- --	Rahuri
7	IPC 2000-52	Phule G 5 X ICCV 10	Kanpur (IIPR)

3.3 CHARACTERS STUDIED

The data were collected on plant basis in F_2 and on plot basis in F_3 yield trial from harvested area of 0.90 X 0.10 m per replication. The observations were recorded for four characters. The technique / method used for measuring the character is described as below.

1) **Number of pods per plant:** Total number of seed bearing pods on individual plant was counted at the time of harvest in F_2 and F_3 generation.

2) **Number of seeds per plant:** Seeds produced by individual plant were counted for this purpose in F_2 and F_3 generation.

3) **Harvest index (%):** This was computed as per the following formula

$$\text{H.I. (\%)} = \frac{\text{Seed yield (g)}}{\quad} \times 100$$

Biological yield was recorded in grams by weighing sun dried whole plant including pods for F_2 individual plant and on plot basis in F_3 generation.

4) **Seed yield per plant (g):** At maturity, plants were harvested, sun dried and threshed to separate out seeds from pods. Seeds were sun dried, cleaned and weighed in

grams. In F_2 generation seed yield was computed on plant basis and in F_3 generation it was on net plot basis.

3.4 STATISTICAL ANALYSIS

3.4.1 Analysis of variance

The data collected from randomly selected F_2 plants and from F_3 progenies for individual character were used for statistical analysis according to randomized block design. The analysis of variance is based on the following linear model.

$$Y_{ij} = \mu + g_i + r_j + \varepsilon_{ij}$$

Where,

Y_{ij} = values of i^{th} genotype in j^{th} replication

μ = general mean

g_i = effect of i^{th} genotype

r_j = effect of j^{th} replication

ε_{ij} = uncontrolled random error associated with i^{th} treatment and j^{th} replication

The form of analysis of variance as presented in Table 3.2 was constructed separately for individual characters.

Table 3.2 Analysis of variance

Source	d.f.	Mean sum of squares	Expected mean squares
Replications	(r-1)	M_r	$\sigma_e^2 + g\sigma_r^2$
Genotypes	(g-1)	M_g	$\sigma_e^2 + r\sigma_g^2$
Error	(r-1) (g-1)	M_e	σ_e^2

Where,

r = number of replication

g = number of genotype

$\hat{\sigma}_e^2$ = error variance

$\hat{\sigma}_g^2$ = genotypes variance

$\hat{\sigma}_r^2$ =replications variance

The standard error of mean (S.Em.) was calculated using following formula.

$$S.Em. = \sqrt{(\hat{\sigma}_e^2 / r)}$$

The critical difference (C.D.) for comparing mean of any two progenies was computed using following formula.

$$C.D. = S.Em. \times \sqrt{2} \times \text{'t'}$$

Where,

't'= Table value of 't' at 5 % level of significance and error degree of freedom.

The coefficient of variation (CV) was determined according to the formula.....

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

Where,

$\overline{X}$ = Overall mean

The data recorded on yield and its components were also subjected to statistical analysis for working out following parameters.

3.4.3 Variability parameters

(a) Mean was calculated for each trait as per following formula.

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

Where,

$\sum$**x =** Sum of measurement for a character

N = The number of sample for a character

(b) 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,

X = individual sample value of a character

N = Number of samples

(c) Coefficient of variation (CV)

$$\text{CV (\%)} = \frac{\sqrt{\text{Variance} \quad (\sigma^2)}}{\overline{X}} \times 100 \quad .$$

Where

$\overline{X}$ = Mean of population.

3.4.4 Correlation coefficients

In the present study, 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 of all the crosses. The general formula for calculating simple correlation coefficient is as under.

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

Where,

Rxy = Simple correlation coefficient between variables x and y

$CO\hat{V}$ (xy) = Covariance between two variables x and y in F_3 population

$\hat{\sigma}^2$ x = Variance of x variable

$\hat{\sigma}^2$ y = Variance of y variable

Test of significance

The test of significance for correlation value was done by calculating the 't' value using following formula.

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

Where,

t = Calculated value of't'

r = Correlation coefficient

n = 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.

3.4.5 Intergeneration analysis

It was carried out by calculating different genetic parameters as follows.

Heritability was calculated according to Cahaner and Hillet (1980).

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

Where,

g_2 = Second generation

g_3 = Third generation

Genetic advance under selection (Gs) was calculated as per Allard (1960)

$$Gs = K \times \sqrt{\text{variance of progeny }(g_3)} \times h^2$$

Where,

K = selection differential

(Value of K at 5 selection intensity = 2.06)

Genetic advance (GA) as percentage of mean was computed as per following formula.

$$\text{GA as (\%) of mean} = \frac{Gs}{\overline{\overline{X}}} \times 100$$

Where,

Gs = Expected genetic advance under selection for a population

$\overline{X}$ = Mean of F_3 population.

Parent – offspring correlation according to Frey and Horner (1957) between single F_2 plant characters and the characters measured in F_3 line in a cross was estimated as follow

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

b' = byx= rxy = σ

b' =ryx $\pm$ S.E. of ryx

cov(xy)= co-variance between parents and progenies

byx = regression co-efficient of parents on progenies

ryx = correlation co-efficient between parents and progenies.

Realized Heritability was computed as per the formula described by Alexander *et al.* (1984)

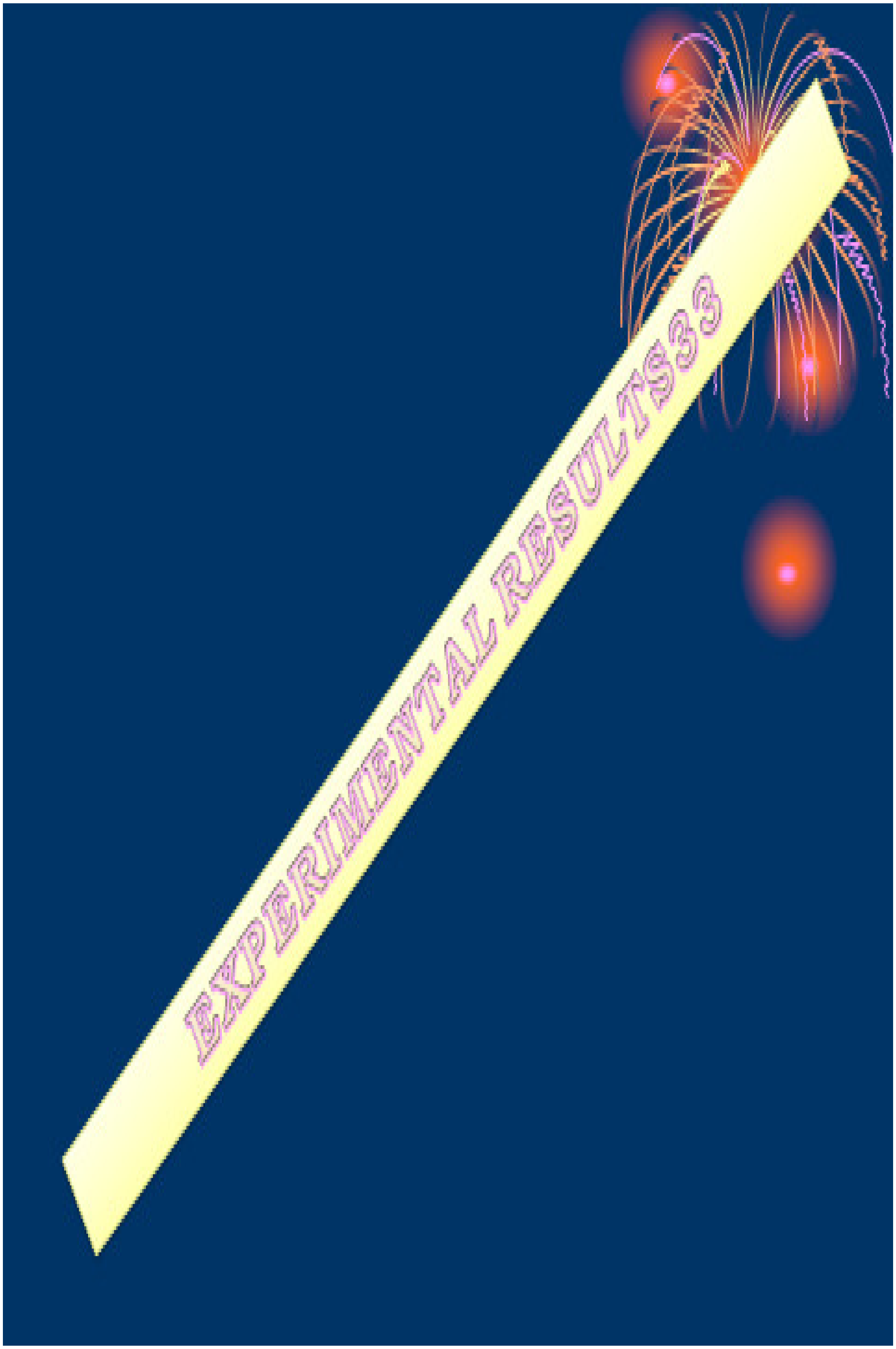
$$h^2 = \left[\frac{\overline{H}\ F_{t+1} - \overline{L}\ F_{t+1}}{\overline{H}\ F_t - \overline{L}\ F_t}\right]$$

Where,

H and L refer to mean value of high and low F_2 plants and F_3 line means for a specific character. The subscripts F_1 and F_{1+1} denote the generation in which selection occurred and the subsequent generation in which the response is measured, respectively.

3.4.6 Test of significance for mean of high and low selection group

The test of significant differences between the mean values of high and low selection group of each selection criteria, the Student 't' test was employed.


EXPERIMENTAL RESULTS33

IV EXPERIMENTAL RESULTS

In the present investigation, an attempt has been made to measure effectiveness of selection in early generations through estimation of variability parameters, correlation among seed yield and its components and response to selection for high and low expression of the traits under study in segregating populations of five chickpea 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 ICP 2000-52 (Cross 4) and JCP 27 x CSJ 103 (Cross 5), hereafter refereed to as Cross 1, Cross 2, Cross 3, Cross 4 and Cross 5, respectively. Within each cross, the ten highest scoring and the ten lowest scoring F_2 derived F_3 progenies were evaluated in a randomized block design with three replications. The mean values for individual character of F_3 progenies are summarized in Appendix-I. The results obtained on genetic variability, correlation, realized heritability, intergeneration relationship as well as direct and indirect selection based on yield and its components are presented here under.

4.1 Analysis of variance

Mean squares due to various sources in F_2 of five chickpea crosses for four characters are presented in Table 4.1. A perusal of the data indicated that the mean squares due to genotypes were highly significant for all the characters, suggesting presence of large amount of genetic variability among the genotypes. Further partitioning of genotypic variation into variation due to parents, crosses and parent *vs.* crosses indicated that the mean squares due to all these three sources were highly significant for all the characters, indicating large amount of variability among parents, crosses and presence of heterotic effects in F_2, respectively. The crosses showing higher mean would be relatively effective in identifying the superior segregants.

Analysis of variance for F_2 derived F_3 progenies on the basis of high and low selection for pods per plant, seeds per plant, seed yield per plot and harvest index (Table 4.2) indicated that mean square due to crosses (C), selection groups (S) and C x S for all the selection criteria were highly significant for all the characters, except C x S for pods per plant in the selection criteria of pods per plant and harvest index, suggesting presence of large amount of genetic variability among the crosses and effectiveness of selection for high and low group within each selection criterion.

Table 4.1 Analysis of variance for four characters involving seven parents and F_2 populations of five crosses in chickpea

Source	df	Pods/ plant	Seeds/ plant	Seed yield/ plant (g)	Harvest index (%)
Replications	2	0.07	1.92	0.08	1.32
Genotypes	11	159.67*	311.52*	6.82*	107.25*
Parents	6	191.04*	248.27*	7.99*	150.32*
Crosses	4	127.41*	118.85*	5.70*	69.85*
Parents *vs* Crosses	1	344.66*	771.91*	12.39*	210.64*
Error	22	6.57	8.99	0.21	5.76

* Significant at 5 % level

Table 4.2 Mean sum of square for four characters of F_3 lines derived from high and low selection groups of five crosses in chickpea

Source	df	Pods/ plant	Seeds/ plant	Seed yield/ plot (g)	Harvest index (%)
Selection criterion: Pods per plant					
Replications	2	8.53	144.16	10.70	29.86
Crosses (C)	4	200.36*	298.06*	948.91*	242.98*
Selection group(S)	1	1692.56*	3118.52*	5010.62*	189.16*
C x S	4	258.66	443*.37	144.18*	3.76*
Error	8	5.72	3.56	4.47	2.02
Selection criterion: Seeds per plant					
Replications	2	0.71	149.55	9.22	29.33
Crosses (C)	4	311.53*	389.66*	869.25*	331.78*
Selection group(S)	1	2018.66*	3146.39*	2253.91*	13.66*
C x S	4	152.28*	314.04*	370.28*	20.50*
Error	8	2.51	3.75	4.33	2.20
Selection criterion: Seed yield per plant					
Replications	2	7.63	138.39	4.34	31.19
Crosses (C)	4	271.92*	385.62*	781.11*	174.99*
Selection group (S)	1	44.23*	362.17*	1385.19*	14.79*
C x S	4	15.57*	17.08*	281.22*	10.39*
Error	8	7.25	4.17	4.72	1.73
Selection criterion: Harvest index					
Replications	2	6.52	145.73	0.19	28.89
Crosses (C)	4	213.65*	259.62*	1272.10*	388.03*
Selection group(S)	1	232.30*	240.41*	1045.21*	264.02*
C x S	4	20.66	16.91*	148.08*	82.26*
Error	8	7.69	4.29	7.34	2.65

* = Significant at 5 % level

4.2 Variability parameters in F_2 and F_3 generations

4.2.1 F_2 generation

4.2.1.1 Pods per plant

The F_2 mean (Table 4.3) varied from 22.83 (Cross 1) to 37.18 (Cross 3) for this character. The range of variation was higher in the Cross 5 (26.00 – 55.00) and narrow in the Cross 3 (20.00 – 39.00). However, the highest value of coefficient of variation (CV) was observed in the Cross 1 (22.91%) and the lowest in the Cross 3 (11.61%).

4.2.1.2. Seeds per plant

Mean seeds per plant of F_2 (Table 4.3) varied from 26.70 (Cross 1) to 49.42 (Cross 3). However, the largest range of variation was expressed (Cross 2) for seeds per plant (36.00 to 68.00). The estimates of coefficient of variation (CV) ranged from 12.86% (Cross 3) to 20.20% (Cross 1).

4.2.1.3. Seed yield per plant (g)

The F_2 mean varied from 3.38 g (Cross 1) to 6.35 g (Cross 3) for seed yield per plant (Table 4.3). The F_2 plant of the Cross 3 expressed higher seed yield per plant (6.35g) than those of the other crosses studied. The range of variation (4.80 – 9.90) in the Cross 2 was higher but CV highest in the Cross 1 (26.48%). The Cross 4 expressed low CV (12.95%) for this character.

4.2.1.4. Harvest index (%)

Mean values presented in Table 4.3 for harvest index indicated that mean harvest index was the highest in the Cross 5 (35.29%) and lowest in the Cross 1 (24.52%). The range of variation was larger (22.26 – 69.33) for this character in the Cross 2. The value of CV for harvest index was higher in the Cross 2 (24.81%) and lower in the Cross 5 (12.76%).

4.2.2 F_3 generations

The mean, range and coefficient of variation for pods per plant, seeds per plant, seed yield per plot and harvest index of F_3 lines derived from high and low expression of pods per plant, seeds per plant, seed yield and harvest index in five chickpea crosses are presented in Table 4.4.

4.2.2.1 Pods per plant

The mean F_3 value of pods per plant (Table 4.4) in the high selection group was the highest in the Cross 2 (88.67) and the lowest in the Cross 3 (61.68). Whereas, in low selection group, it was the highest in the Cross 1 (70.29) and the lowest in the Cross 5 (50.16). Range of variation for this character was larger in high selection group as compared to low selection group in all the crosses, except Cross 1 and Cross 2 in which reverse was the case. Difference in lower and upper values of range was found to be higher for high selection group in the Cross 3 (78.67) and lower for low selection group in the Cross 5 (35.75). Likewise, coefficient of variation (CV) varied from 14.75 % in the

Cross 5 to 37.01% in the Cross 3 in high selection group and in the low selection group it varied from 13.87% (Cross 4) to 29.72% (Cross 2).

4.2.2.2 Seeds per plant

Among the crosses, Cross 4 (109.17) showed the highest and Cross 3 (79.91) showed the lowest mean value in the high selection group (Table 4.4). Whereas, in low selection group, the mean value was the highest in the Cross 1 (87.93) and the lowest in the Cross 5 (63.44). The range of variation for seeds per plant was larger in high selection group as compare to low selection group in Cross 1, Cross 2 and Cross 4. The difference between lower and upper limits of range was found larger in the Cross 3 (101.41) of low selection group and smaller in Cross 4 (39.11) of same selection group. The CV in low selection group varied from as low as 11.94% in the Cross 4 to as high as 34.08 % in the Cross 3. In high selection group, it varied from 18.44 % (Cross 5) to 21.02 % (Cross 2).

4.2.2.3 Seed yield per plot (g)

The estimates of mean value of seed yield per plot (Table 4.4) indicated that high selection group expressed the highest seed yield of 121.35g in the Cross 3 and the lowest of 81.85g in the Cross 4. Whereas, in low selection group the mean seed yield per plot was the highest in the Cross 5 (95.12g) and the lowest in the Cross 4 (79.91g). The range of variation was observed to be higher in high selection group of the Cross 3 and narrow in low selection group of same cross. The CV ranged from 17.51 % in the high selection group of the Cross 4 to 31.82 % in same selection group of the Cross 3.

4.2.2.4 Harvest index (%)

The mean value of harvest index (Table 4.4) in the high selection group ranged from 41.99% (Cross 5) to 55.57% (Cross 3) and in low selection group the mean values varied from 40.94% (Cross 5) to 64.74% (Cross 3). Range of variation for this character was larger in high selection group as compare to low selection group in all the crosses, except Cross 1. Difference in range variation was larger (41.51%) in high selection group of the Cross 3 and narrow (17.24%) in the low selection group of the same cross. The CV varied from 10.03 % in the Cross 1 to 28.23 % in the Cross 4 for high selection group and from 7.79 % in the Cross 3 to 13.92 % in the Cross 2 for low selection group.

Table 4.3 Mean, range and coefficient of variation (CV) for pods per plant, seeds per plant, seed yield per plant and harvest index in F_2 generation of five crosses in chickpea

Character/ cross	Mean ± SE	Range	CV%
Pods/plant			
Cross 1	22.83 ± 0.32	12.00 – 36.00	22.91
Cross 2	33.44 ± 0.41	29.00 - 54.00	20.23
Cross 3	37.18 ± 0.26	20.00 – 39.00	11.61
Cross 4	27.52 ± 0.36	30.00 – 55.00	21.90
Cross 5	29.69 ± 0.31	26.00 – 55.00	17.15
Seeds/plant			
Cross 1	26.70 ± 0.33	20.00 – 39.00	20.20
Cross 2	41.35 ± 0.42	36.00 – 68.00	16.73
Cross 3	49.42 ± 0.38	32.00 – 58.00	12.86
Cross 4	40.93 ± 0.37	45.00 – 75.00	14.81
Cross 5	40.24 ± 0.40	32.00 – 59.00	16.67
Seed yield/plant (g)			
Cross 1	3.38 ± 0.05	2.00 – 5.60	26.51
Cross 2	5.69 ± 0.07	4.80 – 9.90	19.02
Cross 3	6.35 ± 0.05	3.80 – 8.20	13.31
Cross 4	4.95 ± 0.04	3.90 – 6.90	12.95
Cross 5	5.17 ± 0.07	4.20 – 8.40	21.70
Harvest index (%)			
Cross 1	24.52 ± 0.28	13.82 – 39.51	19.06
Cross 2	26.94 ± 0.40	22.26 – 69.33	24.81
Cross 3	30.64 ± 0.32	18.14 – 48.04	17.44
Cross 4	30.70 ± 0.27	20.79 – 50.45	14.70
Cross 5	35.29 ± 0.27	20.00 – 39.89	12.76

Table 4.4 Mean, range and coefficient variation (CV) for four characters of F_3 lines derived from high and low selection group of five crosses in chickpea

Crosses	Mean ± SE		Range		CV%	
	High	Low	High	Low	High	Low
Pods/plant						
Cross 1	73.48 ± 1.90	70.29 ± 2.12	43.50-99.67	39.67-100.83	18.97	22.14
Cross 2	88.67 ± 2.24	58.83 ± 2.38	57.42-111.33	30.25-95.83	18.62	29.72
Cross 3	61.68 ± 3.10	58.29 ± 1.48	22.83-101.50	42.42-83.83	37.01	18.65
Cross 4	75.98 ± 2.06	65.52 ± 1.24	55.83-118.00	46.50-83.83	19.90	13.87
Cross 5	78.38 ± 1.57	50.16 ± 1.18	59.83-106.83	29.75-65.50	14.75	17.25
Seeds/plant						
Cross 1	93.64 ± 2.42	87.93 ± 2.20	56.83-128.00	65.50-123.00	19.02	18.36
Cross 2	112.46 ± 3.21	78.16 ± 2.33	84.17-166.12	51.67-126.67	21.02	21.90
Cross 3	79.91 ± 2.17	78.16 ± 3.51	55.67-113.33	28.12-129.53	20.00	34.08
Cross 4	109.17 ± 3.09	82.00 ± 1.33	80.67-168.92	60.67-99.78	20.79	11.94
Cross 5	97.65 ± 2.45	63.44 ± 2.40	69.83-132.83	35.83-109.93	18.44	26.56
Seed yield/plot (g)						
Cross 1	120.10 ± 3.42	92.50 ± 3.35	92.94-181.92	50.21-141.36	20.92	26.60
Cross 2	89.02 ± 2.66	88.41 ± 3.47	53.4-117.36	43. 68-133.32	21.94	28.87
Cross 3	121.35 ± 5.25	92.63 ± 2.21	51.96-190.38	72.9-131.82	31.82	17.58
Cross 4	81.85 ± 1.95	79.91 ± 2.65	59.36-117.54	54.60-128.88	17.51	24.41
Cross 5	104.20 ± 4.12	95.12 ± 3.30	53.04-152.94	41.7-149.52	29.05	25.48
Harvest index (%)						
Cross 1	52.21 ± 0.71	57.85 ± 0.96	43.29 – 65.21	45.38 – 68.98	10.03	12.09
Cross 2	46.37 ± 1.30	53.97 ± 1.02	27.53 – 68.70	41.25 – 67.80	20.64	13.92
Cross 3	55.57 ± 1.14	64.74 ± 0.69	25.69 -67.20	52.54-69.78	15.09	7.79
Cross 4	48.69 ± 1.87	58.11 ± 0.99	30.70-70.98	45.38 – 69.55	28.23	12.58
Cross 5	41.99 ± 0.95	40.94 ± 0.75	27.15-52.80	31.83-52.60	16.62	13.42

4.3 Correlation coefficients in F_2 and F_3 generations

Phenotypic correlation coefficients estimated for all the possible combinations of four characters in F_2 and F_3 generations of individual five crosses are presented in Table 4.5 and described in following paragraphs.

4.3.1 Pods per plant with others

The association of pods per plant with seeds per plant, seed yield per plant and harvest index (Table 4.5) in F_2 generation of five crosses indicated that pods per plant showed significantly positive association with seeds per plant and seed yield per plant in all the crosses, except with seed yield per plant in the Cross 4. Pods per plant also showed significant correlations with harvest index but was positive in the Cross 1 (r=0.17*), Cross 2 (r=0.31**) and Cross 4 (r=0.49**) and negative in the Cross 3 (r= -0.31**) and Cross 5 (r= - 0.17*).

The estimates of correlation coefficient in F_3 generation indicated strong and positive association of pods per plant with seeds per plant and seed yield per plot in all the crosses. Its association with harvest index was significantly positive in the Cross 1 (r=0.35*) and significantly negative in the Cross 4 (r= -0.38*). The Cross 2 (r= -0.30), Cross 3 (r=0.28) and Cross 5 (r=0.11) showed nonsignificant correlation between pods per plant and harvest index.

4.3.2 Seeds per plant with others

In F_2 generation, association of seeds per plant was found significantly positive with pods per plant and seed yield per plant in all the crosses studied (Table 4.5). In contrast, it was significantly negative with harvest index.

When the correlation coefficient was studied in F_3 generation (Table 4.5), the association of seeds per plant with pods per plant and seed yield per plant was significantly positive in all the crosses, but with harvest index it was significantly negative in the Cross 3 (r= -0.33*) and Cross 4 (r= -0.43**) and nonsignificant in remaining crosses.

4.3.3 Seed yield per plant with others

Correlation values of seed yield per plant with other traits when estimated in F_2 generation of five chickpea crosses (Table 4.5), it was revealed that seed yield per plant was associated significantly and positively with pods per plant and seeds per plant in all the crosses, except with pods per plant in the Cross 4. Correlation values between seed yield per plant and harvest index were significant positive in the Cross 1 (r=0.45**) and Cross 2 (r=0.53**) and nonsignificant in remaining crosses.

In case of F_3 generation, the seed yield per plant was correlated significantly and positively with pods per plant and seeds per plant in all the five crosses. Its association with

Table 4.5 Estimates of simple correlation coefficient (r) among four characters in F_2 and F_3 generation (ignoring high and low selection groups) of five crosses in chickpea.

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**

*, ** Significant at 5% and 1% level, respectively

harvest index was significant positive in the Cross 4 (r=0.35*) and Cross 5 (r=0.56**), but nonsignificant in the Cross 1, Cross 2 and Cross 3.

4.4 Response to selection in terms of mean performance

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 are presented in Table 4.6 and described as under.

4.4.1 Pods per plant

The differences between the high and low group, relative to the high group, in the F_2 generation (Table 4.6) ranged from 31.66% (Cross 5) to 61.04% (Cross 1). In case of F_3 generation, this difference was the highest in the Cross 5 (36.0) and the lowest in the Cross 1 (4.34). The per cent relative differences were lower in the F_3 generation when compared with those of F_2 generation in all the crosses, except Cross 5, in which, reverse was the case.

4.4.2 Seeds per plant

The data presented in Table 4.6 revealed that F_2 plants showed higher differences between the high and low group, relative to the high group compared to F_3 lines in all the crosses, except Cross 5. The mean of selected F_2 plants expressed the highest relative differences in the Cross 1 (46.09%) and the lowest in the Cross 4 (30.52). Whereas, differences in mean of high and low F_3 lines varied from 2.19% (Cross 3) to 35.03% (Cross 5).

4.4.3 Seed yield (g)

The differences between the high and low group, relative to the high group, in the F_2 generation was calculated the highest in the Cross 3 (87.70%) and the lowest in the Cross 5 (39.03%). While calculated relative differences in F_3, was the highest in Cross 3 (23.67%) and lowest in Cross 2 (0.69%). In general, per cent differences in F_2 generation were higher in magnitude as compared to those of F_3 generation.

4.4.4 Harvest index (%)

The estimates of differences between high and low selection, relative to high group for selected F_2 plants and F_3 lines their of presented in Table 4.6 revealed that difference in mean of high and low selected F_2 plants was as high as 54.24% in the Cross 1 and as low as 34.55% in the Cross 5. On the other hand, these differences in F_3 lines were negative in all the crosses, except Cross 5, in which it was positive (2.50%). The per cent differences between high and low selection group of F_3 lines in all the crosses were lower as compared to those of selected F_2 plants.

Table 4.6 Mean values of F_2 plants selected for high and low expression and their F_3 lines of five crosses in chickpea

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

4.5 Realized heritability

The realized heritability, though it is not valid estimate of true heritability because of changes in inbreeding due to sequential selfing, but found its usefulness in measuring the effectiveness of selection and comparison of different selection schemes (Falconer, 1960). Realized heritability worked out in present study for seed yield and its components of five crosses in chickpea are given in Table 4.7.

4.5.1 Pods per plant

The highest estimate of realized heritability for pods per plant was observed in the Cross 5 (1.87) and low in the Cross 1 (0.16). High magnitude of heritability was registered in the Cross 5 (1.87) and Cross 2 (1.38). Cross 4 (0.53) expressed intermediate heritability. But the magnitude of heritability was low in the Cross 3 (0.21) and Cross 1 (0.16).

4.5.2 Seeds per plant

The estimates of realized heritability for seeds per plant revealed that its value was the highest in the Cross 5 (1.81) and the lowest in the Cross 3 (0.08). The realized heritability was magnitudinally higher in the Cross 5 (1.81), Cross 2 (1.32) and Cross 4 (1.29) and low in the Cross 1 (0.33) and Cross 3 (0.08).

4.5.3 Seed yield (g)

The values of realized heritability for seed yield per plot indicated that the Cross 5 (2.82) showed the highest realized heritability followed by the Cross 1 (2.71) and Cross 3 (2.68). All the crosses expressed heritability values more than one. In fact, the magnitude of heritability was also high in the Cross 4 (0.78). The Cross 2 (0.14) showed low heritability for seed yield.

4.5.4 Harvest index (%)

Estimation of realized heritability for harvest index indicated that only Cross 5 (0.08) expressed positive value but its magnitude was very low. In remaining crosses, the values of this parameter were negative.

Table 4.7 Realized heritability (h^2 F_2-F_3) for seed yield and its components of five crosses in chickpea

Character	Realized heritabilities				
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 5
Pods/ plant	0.16	1.38	0.21	0.53	1.87
Seeds/ plant	0.33	1.32	0.08	1.29	1.81
Seed yield (g)	2.71	0.14	2.68	0.78	2.82
Harvest index (%)	-0.32	-0.28	-0.45	-0.58	0.08

4.6 Intergeneration analysis

For intergeneration relationships, different genetic parameters like heritability and genetic advance were estimated based on the relationship between two successive generations (Cahaner and Hillet, 1980). Correlations between F_2 plants and derived F_3 lines were also computed. Results of heritability, genetic advance and correlation coefficient are presented in Table 4.8 and described in following paragraphs.

4.6.1 Pods per plant

The data presented in Table 4.8 revealed that estimates of intergeneration heritability between F_2 and F_3 were low in magnitude for pods per plant in all the crosses. However, relatively higher value was observed in the Cross 5 (0.38) followed by Cross 4 (0.34) and Cross 2 (0.31). The genetic advance as percentage of mean ranged from 2.44% (Cross 3) to 21.07% (Cross 5). The Cross 2 (19.37%) and Cross 4 (12.80%) had shown moderate genetic advance.

Correlation coefficient between F_2 and F_3 generation for pods per plant was observed significant and positive in the Cross 5 (r= 0.78**), Cross 2 (r=0.66**) and Cross 4 (r=0.45*). Cross 1 and Cross 3 showed nonsignificant association between two generations for this character.

4.6.2 Seeds per plant

The perusal of data presented in Table 4.8 of heritability, genetic advance as percentage of mean and correlation coefficient for seeds per plant showed that magnitude of heritability was low in all the crosses, which ranged from 0.04 (Cross 3) to 0.31 (Cross 2). Genetic advance was found to be moderate in the Cross 2 (17.59%), Cross 5 (16.56%) and Cross 4 (14.15%) and low in the Cross 3 (2.07%) and Cross 1 (3.98%).

Correlation between F_2 and F_3 mean was significantly positive in the Cross 5 (r=0.71**), Cross 2 (r=0.64**) and Cross 4 (r=0.62**), while Cross 1 (r=0.21) and Cross 3 (r=0.07) showed nonsignificant association between the generations for seeds per plant.

4.6.3 Seed yield (g)

Heritability, genetic advance and correlation values for seed yield presented in Table 4.8 revealed that estimates of heritability varied from 0.01 (Cross 2, Cross 4 and Cross 5) to 0.10 (Cross 1) and genetic advance from 0.14% (Cross 2) to 5.32 % (Cross 1). Correlation coefficient between F_2 and F_3 generation was significantly positive for seed yield in the Cross 1 (r=0.55**) and Cross 3 (r=0.45*), while rest of the crosses showed nonsignificant correlation between the generations.

4.6.4 Harvest index (%)

Estimates of heritability, genetic advance and correlation calculated based on F_2 and F_3 generation of five crosses for harvest index (Table 4.8) depicted that value of heritability and genetic advance as percentage of mean were negative in all the crosses for harvest index.

Correlation coefficient between F_2 and F_3 generation was significantly negative in the Cross 1 (-0.45*), Cross 2 (-0.45*) and Cross 3 (-0.64**). The Cross 4 (r=-0.38) and Cross 5 (r=-0.01) showed nonsignificant values of correlations between two generations for harvest index.

4.7 Seed yield response to direct and indirect selection

The value of yield component selection was measured by the subsequent response of seed yield to selection for these component characters. Mean values for seed yield from direct and indirect selection *via* yield components are given in Table 4.9. The results revealed that when selection was conducted for pods per plant, the difference in seed yield between high and low selection group was significant in all the five crosses (values varied from 17.4g to 39.3g). Similarly, for seeds per plant this difference was significant in the Cross 2 (24.7g), Cross 4 (18.9g) and Cross 5 (36.3g). Significant difference was also observed in the Cross 1 (22.2g), Cross 3 (20.98g) and Cross 5 (12.5g) when

Table 4.8 Estimation of intergeneration (F_2/F_3) heritability, genetic advance (GA) and correlation coefficient for four characters of five crosses in chickpea

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					
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

*, ** significant at 5 % and 1 % level, respectively

selection was practiced for harvest index. Direct selection for seed yield in the Cross 1 (27.6g) and Cross 3 (28.8g) produced significant differences in subsequent high and low F_3 mean.

In other words, the highest selection response of 39.3g was observed in the Cross 5 when the selection was exercised for pods per plant. This cross also exhibited 36.3g difference between high and low mean when selection was done for seeds per plant. Though, the direct selection for seed yield also showed sizeable response to selection to the tune of 28.8g in the Cross 3 followed by 27.6g in the Cross 1.

Table 4.9 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 of five crosses in chickpea.

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

*, ** significant at 5 % and 1 % level, respectively

Diff. = Difference

Discussion

IV DISCUSSION

Early generation testing procedure is more efficient than visual selection for yield improvement in chickpea (Dahiya *et al.,* 1984). Naidu and Dahiya (1987) in chickpea reported that crosses identified as high yielding in F_2 and F_3 had significantly greater mean seed yield in F_4 and F_5. For rapid and effective genetic improvement of any economic traits, it would be advantageous if selection can be carried out in the earliest possible generations so that only best recombinant lines are retained for further testing. The term early generation testing is generally associated with progeny testing from F_3 onwards.

An important objective in most of chickpea breeding programmes is to enhance the genetic potential for seed yield. Because of the low heritability, it has been suggested that indirect selection based one or more of its components might be more effective than direct selection for seed yield itself (Johnson *et al.*, 1966a; Paroda and Joshi (1970) and Alexander *et al.,* (1984). Grafius (1956) suggested that seed yield might be more effectively increased by selection for one or more yield components.

In the present study, the relative effectiveness of high and low selection of individual F_2 plants in chickpea was based on (i) seed yield per plant,

(ii) pods per plant (iii) seeds per plant and (iv) harvest index with evaluation of seed yield and its components of derived progenies in F_3 generation.

5.1 Variability Parameters in F_2 and F_3 generations.

Estimation of variability parameters of a trait is important in determining the response of that trait to selection. In the present study, the variability parameters like mean, range and coefficient of variation (CV) were calculated to determine the relative effectiveness of selection in F_2 derived F_3 progenies of five chickpea crosses.

Mean, range and coefficient of variation (CV) for yield and its components of F_2 plants (Table 4.3) and F_3 progenies of high and low selection groups (Table 4.4) were derived either on individual plant basis or on plot basis. Pods per plant and seeds per plant were based on individual plant in both the generations. Whereas, harvest index was calculated on individual plant basis in F_2 generation and on plot basis in F_3 generation. In fact, harvest index is expressed on percentage basis; therefore, comparison between F_2 plants and their F_3 progenies is possible. Such comparison is not possible for seed yield, as it was recorded on individual plant basis in F_2 generation and on plot basis in F_3 generation.

Nevertheless, comparison on CV values between these two generations is possible as it is unitless estimate.

A perusal of the data for F_2 generation and F_3 generation indicated that the 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 values for pods per plant, seeds per plant and harvest index are higher of both high and low selection group as compared to mean values of F_2 generation. This indicated the predominance influence of non additive gene action for these characters.

Mean values of F_3 selected progenies indicated 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 mean harvest index for high selection group was lower than that for low selection group in all the crosses, except Cross 5. This indicated that the 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.

The estimates of coefficient of variation (CV) for F_2 generation (Table 4.3) and for selected high and low F_3 progenies (Table 4.4) revealed that the magnitude of CV was high (>20%) for pods per plant in three F_2 crosses. Such high magnitude of CV for this character was observed in one F_3 cross for high selection group and in two F_3 crosses for low selection group. Seeds per plant exhibited high magnitude of CV in F_2 generation of one cross but number of crosses increased to three in each of the high and low selection F_3 progenies. Likewise, for seed yield, the number of crosses increased from two in F_2 to four in each of the high and low selection F_3 progenies. One cross registered high CV for harvest index in F_2 but two crosses had shown high CV for high harvest index F_3 progenies.

Thus, results for present study indicated that variability in F_3 generation more or less increased due to selection for high and low expression of all the traits. Boerma and Cooper (1974a) have observed decreasing coefficient of genetic variability with each generation of selection in four soybean crosses. Results of the present study are quite unexpected as selection for high and low expression would result into decreasing variability because of bidirectional shift in mean performance. However, the possibility of genetic differentiation for increasing variance due to inbreeding in successive generation can not be ruled out (Khalifa and

Qualset, 1975). Further, Hanson (1959) showed that genetic variance would be expected to increase in successive generation for those crosses with a predominant repulsion phase linkage.

5.2 Correlation coefficients in F_2 and F_3 generations

Improvement of complex character like yield may be accomplished through component breeding. In this method, there should be strong association of yield with a number of characters. Adebisi *et al.,* (2004) reported that crop improvement depends upon the magnitude of genetic variability present in the base population and once genetic variability has been ascertained in a crop, improvement is possible by using an appropriate selection method.

One of the objectives of present study was to know the impact of selection on the association of seed yield and its component characters. Selections for high and low expression of individual character in F_2 generation was conducted and F_3 selected progenies thereof were studied in F_3 generation.

The correlation coefficients for yield and other characters estimated in F_2 generation are based on individual 225 plants in a cross, whereas, in F_3 generation, the estimations are based on 10 high and 10 low selected F_3 progenies. As both the generations were grown in consecutive seasons, the results may be influenced by season differences. However, increase or decrease in correlation with advancing the generation was considered to be indicative of effects of high and low selection which might have caused bidirectional shift for mean performance. 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 more stronger in F_3 generation of all the crosses, except for pods per plant with seed yield in the Cross 4, in which, nonsignificant association was shifted to significant positive. Increasing in magnitude of correlation among different traits with advancement of generation in chickpea have been reported by Salimath and Patil (1990).

Effect of F_2 selection on correlation of harvest index with other traits in F_3 was observed to be inconsistent. 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 correlations, three became nonsignificant with opposite sign in F_3 generation. Whereas, in the Cross 4, significant positive correlation between these two characters of F_2 changed to significant negative in F_3.

In case of correlation between harvest index and seed yield, the association shifted from significant to nonsignificant in two crosses and from nonsignificant to significant in other two crosses. Similar observations were also reported by Khisore and Gupta (2002) in lentil and suggested 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. The possible reason for the difference in associations from generation to generation may be because of the high degree of segregation and genetic heterozygosity in the F_3 generation leading to the breakdown and formation of new linkages. Increasing in correlation values with advancement of generation through selection for yield was also observed by Whan *et al.* (1981) in wheat.

The changes in correlation coefficient in the present study to be most probably due to directional selection which operated in high and low selection groups, though the influence of season difference on the results should be taken into consideration. Consistent changes in increasing strength of correlations among pods per plant, seeds per plant and seed yield with few exception indicated that selection for these component characters might have of good impact on seed yield improvement and effectiveness of indirect selection.

Shifting in correlations of harvest index with other characters was found to be cross dependent. This suggests that selection for harvest index would be effective only in those genetic backgrounds which had shown favourable changes. Sharma and Smith (1986) also reported variations in correlation between harvest index and grain yield in the F_2 and F_3 generations in wheat. Whan *et al.* (1981) concluded from their relationship studies in derived lines of wheat that selection for harvest index in early generation was unlikely to be more effective than selection for yield itself.

5.3 Response to selection in terms of mean performance

It is evident that the difference between high and low selection groups for pods per plant, seeds per plant and seed yield was positive in both the generations (Table 4.6). The negative or low difference was estimated for harvest index in all the F_3 crosses. Thus, selection in F_2 for high expression was found effective in identifying F_3 progenies for higher pod number, seed number and seed yield and not for high harvest. Low difference for harvest index indicated that optimum genetic level for this character may vary depending on environment (Rasmusson and Cannell, 1970).

The per cent mean difference, relative to the high group (H-L/H x 100) in F_2 generation ranged from 30.53 to 87.70 %, while in F_3 generation, this range was observed from -19.35 to 36.00 %. Thus, lower and upper limits of the range decreased with the advancement of generation. In case of selected F_2 plants, the per cent mean differences for seed yield were higher compared to those for component traits. Such trend in F_3 lines was not observed for seed yield and the component traits.

Further, it was observed that with few exceptions, the per cent differences between high and low group decreased in derived F_3 lines compared to parental F_2 plants for all the characters. Reduction of per cent mean difference in derived F_3 lines was more pronounced and even negative in four out of five crosses when selection was conducted for harvest index. Higher selection differences in F_2 selected plants and negative or low responses in F_3 for this trait indicated that selection for harvest index could be misleading due to genotype x environment interaction as both the generations were grown in different years. Our results are in agreement with those reported by Whan *et al.* (1982) in wheat.

On the whole, the mean expression of F_2 high selection groups maintained high performance in their F_3 lines. However, per cent mean difference between high and low selection group was found reduced in derived lines. This reduction was cross and character dependent, also even negative in some of the crosses for harvest index. The reduction in difference between high and low group in the F_3 generation compared to that in the F_2 generation for various characters have also been reported by Alexander *et al.* (1984) in winter wheat.

Relatively larger difference between high and low groups of pod number, seed number and seed yield suggested that selection would be effective for improvement of those characters. 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).

5.4 Realized heritability

Though not valid estimates of true heritabilities because of changes in inbreeding due to sequential selfing, these realized heritability estimates are useful measures both of the effectiveness of selection and comparison of different selection scheme (Falconer, 1960).

The realized heritabilities (Table 4.7) were, in general, higher for seed yield compared to its component traits. The actual values for seed yield ranged from 0.14 to 2.84. However, in terms of magnitude, these values were low (<0.40) in the Cross 2 and high (>0.70) in the rest of the crosses. Seeds per plant revealed low magnitude in two crosses and high magnitude in remaining crosses. Likewise, pods per plant expressed high realized heritability in two, moderate in one and low in two crosses. Very low magnitude of realized heritability was observed for harvest index in all the crosses.

Thus, results suggest that progress could be made in a breeding programme by selecting for seed yield itself. To some extent, selection for pods per plant and seeds per plant was also found effective as certain populations expressed high magnitude of realized heritability. Very low realized heritability estimates for harvest index probably reflects limited genetic variability or influence of genotype x environment interaction and also indicates ineffectiveness of selection on the basis of this trait. Singh and Singh (1997) also reported ineffectiveness of early generation selection for harvest index in wheat.

The realized heritabilities in present study were estimated as the ratio of response to selection (High F_3 mean – Low F_3 mean) to the selection differential (High F_2 mean – Low F_2 mean) for a particular trait. Thus, these values are not valid estimates but indicative of relative effectiveness of selection for three components and yield. Therefore, it is assumed that when the response to selection in F_3 is greater than the selection differential of F_2, the realized heritability values would be greater than one as observed for seed yield, seed number and pod number in some of the crosses under study. On the other hand, when the response to selection is negative, i.e., mean of high F_3 progenies lower than mean of low F_3 progenies, the realized heritability values would be negative as observed for harvest index in four out of five crosses. This may occur due to genotype x environment interaction. Wrong and Baker (1986) calculated realized heritability, which varied from -8 to 186 % depending on cross and environment, whereas, Singh and Singh (1997) reported negative realized heritability for certain characters in wheat.

Inconsistent and cross dependent realized heritability for yield and its components as observed in the present study was also reported earlier in chickpea (Bisen *et al.*, (1985). Genotype x environment interactions would be involved for inconsistency in the results since F_2 and F_3 generations were grown in two different seasons (Bisen *et al.*, 1985).

It is seen from our results that routine selection on components would be unwise. Although, selection for seeds per plant in the Cross 2, Cross 4 and Cross 5 as well as for pods per plant in the Cross 2 and Cross 5 may be rewarding. The strong association between these two traits and of them with seed yield in parental F_2 populations and derived F_3 progenies (Table 4.5) support these results.

5.5 Inter-generation analyses

Recombination breeding has been mostly recognized as successful method for breeder to develop new varieties. This involves a systematic selection initiated in the early segregating generation such as F_2, which exhibits wide array of variance among segregating generations. Selection made in early segregating generation (F_2) is the result of cumulative effect of both genotype and environments. Testing of performance of third generation progenies which is more dependable on that of second generation performance and relationship studies between the two successive generations are the better indicative of effectiveness of selection.

There are two alternative methods open to the breeder for improving the rate of response to selection, one by increasing the heritability and other by reducing the proportion of selected genotypes with increasing selection intensity. The heritability can be increased only by reducing environmental variation. Reducing the proportion of the individuals selected, seems at first sight to be straight forward means of improving the response but there are several factors to be considered which set a limit to what the breeder can do in this way (Falconer, 1960).

Parent-progeny correlation and intergeneration heritability and genetic advance are the ways of ascertaining environment influence on different traits (Lush, 1940). The heritability and genetic advance as percentage of mean for yield and its components in five chickpea crosses worked out based on the relationship between two successive generations viz., F_2 and F_3 (Table 4.7), revealed that the heritability estimates were low (> 0.40) for all the characters under consideration. Relatively higher values were observed for pods per plant and seeds per plant in the Cross 5, Cross 4 and Cross 2. Seed yield and harvest index manifested very low heritability. Similar observations were made by Padi and Ehlers (2008) and Padi (2008) for grain yield in cowpea.

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. Moderate genetic advance was also observed for seeds per plant in the Cross 2, Cross 5 and Cross 4. In all other cases genetic advance was low (<10). Thus, with few exceptions, all the characters were highly influenced by environment. Ahn *et al.* (1982)

estimated low heritability and low genetic advance between F_2 and F_3 generations.

The intergeneration correlation between F_2 and F_3 generation (Table 4.8) showed significant positive values for pods per plant and seeds per plant in three crosses and for seed yield in two crosses. Harvest index showing significant negative correlations are in close agreement with those reported by Rana and Gupta (1993) in pea and Mehta (2002) in cowpea. The Cross 5 recorded significant correlation values and low heritability coupled with high genetic advance for pods per plant. This indicates that pods per plant was under the control of sizeable portion of additive gene action and selection for pods per plant in this population may be fruitful for improving this trait.

The correlation between generations added further evidence that pods per plant and seeds per plant in the F_2 generation of Cross 2, Cross 4 and Cross 5 were good predictor of respective characters in the F_3 generation. Similarly seed yield was found good predictor of seed yield in the Cross 1 and Cross 3.

Since low or negative relationships exhibited between generations for the measured traits and strong associations found to be established between seed yield and selection criteria (pods per plant and seeds per plant) within F_2 and F_3 generation (Table 4.5) 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). In addition to genotype x environment interaction, differential segregation and gene recombination in early segregating generations might be the probable reasons for low parent-offspring correlation coefficient (Bhagowati and Hazarika, 2004).

In fact, selection for one trait to increase or stabilize seed yield is dependent on the extent of compensatory effect in the other characters determined by environment and genetic background. Gedge *et al.* (1978) concluded while studying heterogeneous soybean lines that effectiveness of early generation testing is influenced by genotype x environment interaction, low heritability and inter- genotypic competition among individuals within a line. As in the case of present study, often nonsignificant inter-generation correlation for seed yield has been reported by Rahman and Bahl (1986) in chickpea. Whan *et al*, (1981) recorded correlation between different generation often nonsignificant and concluded that while gains in 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.

5.6 Direct and indirect selection

Selection of promising plants in early segregating generations that may eventually give rise to high yielding pure lines in subsequent generations has been a major challenge to the breeder of the self pollinated crops. In early stages of breeding programmes, direct estimates of yield are quite difficult. Plant breeders are commonly selecting for yield components which indirectly increase yield. Yield component breeding to increase yield would be most effective, if the components involved were highly heritable and genetically independent or positively correlated.

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. In the present study, the value of yield component selection is measured by the subsequent response in seed yield to selection for these component characters. Selection was considered effective when the mean values of the high and low lines differed significantly from each other.

Seed yield difference between high and low selection group (Table 4.9) was significant in all the crosses when selection was practiced for pods per plant, whereas, three out of five crosses showed significant yield differences when selection was conducted for seeds per plant and harvest index. When selection was exercised for high and low seed yield in F_2 generation, the resulted F_3 progenies recorded significant mean seed yield difference between them in two out of five crosses studied.

In general, selection for yield and its components resulted in a positive response to seed yield, which ranged from 1.6g to 39.3g 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. These results are in agreement with those obtained in chickpea by Kumar and Bahl (1992), in barley by Rasmusson and Carnell (1970) and in wheat by Alexander *et al.* (1984), who observed large yield gain through component selection rather than direct selection in certain populations under study.

Pods per plant selection criterion showed significant mean seed yield difference between high and low selection group in all the crosses. In the Cross 1 and Cross 3 indirect selection for harvest index and direct selection for seed yield gave significant positive response in yield. High harvest index and high seed yield progenies of these two populations exceeded at least by 20.9g than the low harvest index and low seed yield.

Thus, our results indicate 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. Ineffectiveness of selection for harvest index and seed yield in many genetic backgrounds could be due to environment and not due to genotype as indicated by weak relationships and low heritability coupled with low genetic advance between the generations for these traits (Table 4.8). Dahiya *et al.* (1984) reported early generation yield testing as more efficient selection procedure for yield improvement in chickpea.

5.7 Identification of superior lines

Identification of superior lines is another direct measure of the effectiveness of direct/indirect selection for seed yield and its components in early segregating generations. 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 present 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

5.1). The high seed number of the F_2 plants was the second most important selection criterion. Response to selection of F_2 plants based on seed yield *per se* and harvest index was poor. Response to selection of F_2 plants based on harvest index was reported ineffective by Alexander *et al.* (1984) and Sharma and Smith (1986) in wheat. 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 of the highest yielding F_3 progenies of the Cross 1 (progeny number 003) and similarly two of the highest yielding F_3 progenies of the Cross 2 (progeny number 038 and 043) were derived from selected F_2 plant for high seed yield (Table 5.1). These parent F_2 plants were also selected for high expression of pod number and seed number per plant as well as for high harvest index. This suggests that more number of pods and seeds contributed in equal measure to both the higher harvest index and higher seed yield. This may be attributed to significant and positive correlation of seed yield with pods per plant, seeds per plant and harvest index in these two parental populations (Table 4.5).

In contrast, the highest yielding F_2 selected F_3 progenies of the Cross 1 (progeny number 034, 035 and 033), Cross 2 (progeny number 075 and 079), Cross 4 (progeny number 185,183 and 179) and Cross 5 (progeny number 223 and 222) were derived from F_2 selected plants for low selection group of any one of the measured traits. These plants were not in the selection group for any other characters, showing that an optimum balance of those characters possessing neither high nor low selection groups of these traits may be resulted in high yielding lines (Alexander *et al.* 1984 and Singh and Balyan, 2003).

The five best F_3 progenies across the crosses were belonging to the Cross 3 (progeny number 109, 102, 107, 091 and 098). These individual progenies were 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 due to the genotype x year interaction, as comparison of the generations was made of different years and may also be due to failure of heterozygous high yielding genotypes to breed true due to segregation in the succeeding generations (Singh and Balyan, 2003).

Among the crosses studied, the selection criteria observed to vary from cross to cross. In the Cross 1, the harvest index was found to be the best selection criteria. Whereas, in the Cross 2 pod number, seed number and seed yield per plant were found to be equally important for improving seed yield. None of the characters played important role for yield improvement in the Cross 3, though the average yield of 10 best F_3 progenies of this cross was higher than that of F_3 progenies of any other crosses. Pod number and seed number per plant appeared to be important to some extent in the Cross 4, While Cross 5 exhibited high pod number, high seed number and high harvest index as better selection criteria, as half of the progenies derived from high selection group of these characters.

The results of this study suggested that the effectiveness of selection involving the measured traits varied from cross to cross. However, selection for pods per plant was usually found more effective than the other traits. 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.

Table 5.1 Ten highest yielding F_2 selected F_3 lines and the pattern of selection group of their parental F_2 plants of five crosses in chickpea

Crosses	Progeny No.	F_3 yield g/plot	Traits selected in F_2			
			Pods/ plant	Seeds/ plant	Seed yield/ plant(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

Table 5.1 contd...

Crosses	Progeny No.	F_3 yield g/plot	Traits selected in F_2			
			Pods/ plant	Seeds/ plant	Seed yield/ plant(g)	Harvest index (%)
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

High, low and non selected are designated by H, L and NS, respectively

SUMMARY AND CONCLUSIONS

V SUMMARY AND CONCLUSION

In chickpea, handling of segregating generations poses a great difficulty to the breeders because of limited available resources. Therefore, one is always in search of alternative to minimize the size of populations to be handled in advanced generations but at the same time wants to retain the best recombinant lines for the traits under improvement. Early generation selection is a cogent answer to the problem. Therefore, the present study was carried out in five cross derived population in chickpea.

The experimental material consisted of F_2 and F_3 generations of five crosses involving seven parents of chickpea. The experiment was laid out in randomized block design with three replications at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh by growing F_2 during *Rabi* 2006 and F_3 during *Rabi* 2007 under irrigated condition. From the available plants in F_2 generation, 10 highest scoring and 10 lowest scoring plants for seed yield per plant, number of pods per plant, number of seeds per plant and harvest index, were selected. The F_3 progenies of the selected F_2 plants were grown in succeeding *Rabi*-07. The data collected for four characters were analyzed for mean, range, coefficient of variation, correlation, realized heritability, genetic advance and inter generation relationships.

The salient features of findings of the present investigations are as under.

1. The mean sum of squares due to F_2s and F_3s genotypes were highly significant, suggesting presence of large amount of genetic variability.
2. Mean values of F_3 progenies indicated that selection for high pods per plant, seeds per plant and seed yield maintained their performance higher than low level. However, environmental effect was found pronounced on harvest index as mean values of F_3 high selection group was lower than that of F_3 low selection group, which probably means that the superior of individual selection made in F_2 for high expression was more due to environment than due to genotype.
3. The numbers of crosses showing high magnitude of coefficient of variation were increased in F_3 as compared to F_2 generation for all the characters, except pods per plant. The results are quite unexpected; otherwise variance (CV) in next generation should be decreased due to bidirectional selection. However, genetic variance may be increased in succeeding generation if predominant repulsion phase linkage is present.
4. Consistent increasing in correlations among pods per plant, seeds per plant and seed yield with advancement of generation through

selection, except few combinations indicated that indirect selection for these component characters may be effective for seed yield improvement in chickpea.

5. Variation in correlation values of harvest index with other traits in F_2 and F_3 generation was cross dependent. Thus, selection for harvest index would be effective only in those genetic backgrounds which had shown favourable changes in F_3 generation.

6. As compared to F_2 generation, the per cent mean differences, relative to the high group (H-L/H x 100) were decreased with the advancement of generation for all the characters. However, these reductions were more pronounced and even negative in four out of five crosses when selection was conducted for harvest index. Relatively large difference between high and low groups of pod number, seed number and seed yield suggested that selection would be effective for improvement of those characters.

7. Estimates of realized heritability for yield and its components in the present study were inconsistent and cross dependent. The realized heritabilities were higher for seed yield compared to its components traits. This suggests that progress could be made in a breeding programme by selecting for seed yield itself. However, selection for pods per plant and seeds per plant found effective to some extent in

certain populations as they expressed high magnitude of realized heritability. Very low realized heritability for harvest index probably reflects limited genetic variability and also indicates ineffectiveness of selection on the basis of this trait.

8. Intergeneration analysis indicated that heritability was low for all the characters under consideration. Relatively higher values were observed for pods per plant and seeds per plant in the Cross 5, Cross 4 and Cross 2. Seed yield and harvest index manifested very low heritability.

9. The magnitude of genetic advance as percentage of mean for pods per plant was high in only one cross and moderate in two crosses. A seed per plant expresses moderate magnitude of genetic advance in three out of five crosses.

10. Looking to the low heritability and low genetic advance between F_2 and F_3 generations for most of the characters and crosses, it can be inferred that characters under consideration were highly influence by environment.

11. The intergeneration correlation between F_2 and F_3 generation showed significant positive correlation values for pods per plant and seeds per plant in three crosses and for seed yield in two crosses. Harvest

index showed significant negative correlation in three and nonsignificant correlation in two crosses.

12. In general, selection for yield and its components resulted in a positive response to seed yield. However, seed yield difference between high and low selection group was significant in all the crosses when selection was done for pods per plant. Three crosses for harvest index selection and two crosses for seed yield selection recorded significant difference between mean seed yield of high and low group. Thus, results indicate that selection for high pod number is effective, whereas, selection for high harvest index and high seed yield may be rewarding only in certain genetic backgrounds.

13. There was no definite pattern for identification of superior yielding lines by selection for yield and yield component traits. Effectiveness of selection involving the measured traits varied from cross to cross. However, selection for pods per plant was usually found more effective than the other traits. Some superior yielding lines were identified by selection for all the traits; whereas, yield increment in some of the progenies was obtained even in the absence of high expression of all the traits. On an overall of five crosses, 40 % high yielding F_3 progenies were derived from selected F_2 plants for high

pods per plant. This indicates the moderate success for selection of high yielding progenies based on F_3 yield test.

Conclusion

The results of the present study indicated that indirect selection through pods per plant was highly effective in altering seed yield. Selection for yield through other components and seed yield itself was effective in certain situations, but could not be recommended as a routine procedure. Selection of F_2 plants with high expression of pod number resulted into 40 % of the highest yielding F_3 progenies, which indicate moderate efficiency of yield testing in F_3 generation for identification of high yielding progenies. Even when yield response to direct and indirect selection was positive, some superior yielding lines were not identified by selection for any trait. Realized heritability estimates were inconsistent and cross dependent. Besides this, inconsistent relationships and low heritability coupled with low genetic advance between two generations for the selection criterion in many genetic backgrounds indicated the influence of environment on the effectiveness of selection.

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* Original not seen

Appendix-1

APPENDIX-I

Mean values for yield and its components of F_3 progenies derived from F_2 selected plants of five crosses in chickpea

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
Cross 1					
001	HP, HY, HH,	84.56	102.25	101.78	44.66
002	HP, HS, HY, HH	64.92	66.67	93.54	54.67
003	HP, HS, HY, HH	77.00	83.17	124.45	58.55
004	HP, HY, HH	80.50	105.89	170.23	61.70
005	HP, HS, HY	85.08	107.75	144.70	55.61
006	HP, HY	70.58	83.92	114.30	57.98
007	HP, HS, HY	45.25	53.75	112.50	46.43
008	HP, HS, HY, HH	85.17	93.31	85.43	55.78
009	HP, HY	63.08	67.47	120.13	54.31
010	HP, HS, HY	78.67	88.25	110.09	59.68
011	HS	89.00	92.50	114.30	50.27
012	HS	60.08	88.90	87.66	62.45
013	HS	70.58	83.92	96.92	45.52
014	HS	63.86	105.07	85.06	39.94
015	HH	83.08	92.12	157.93	52.13
016	HH	71.58	94.50	114.84	44.65
017	HH	58.85	92.20	121.22	49.23
018	HH	67.42	69.84	111.90	53.73
019	HH	76.67	95.00	110.09	55.98
020	LP, LS, LY, LH	52.06	73.25	97.52	35.56
021	LP, LS, LY, LH	55.06	69.67	64.93	36.33
022	LP, LY, LH	71.00	82.50	119.75	54.86
023	LP, LY, LH	92.83	118.50	108.36	48.73
024	LP, LS, LY	77.33	87.00	129.91	58.45
025	LP, LY	89.00	92.50	96.92	45.39
026	LP, LS, LY	75.83	88.58	55.93	48.99
027	LP, LS, LY, LH	44.58	55.67	103.13	41.85
028	LP, LY, LH	69.33	74.00	86.69	46.01
029	LP, LY, LH	75.83	95.33	126.18	58.87
030	LS	52.06	73.25	101.78	43.66
031	LS	64.25	80.83	66.20	37.24
032	LS	53.50	71.03	90.47	42.84

Appendix-I Contd…

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
033	LS	71.00	82.50	124.45	68.81
034	LS	92.83	118.50	170.23	79.54
035	LH	82.45	105.75	131.06	67.28
036	LH	91.00	84.92	99.06	57.15
037	LH	79.15	57.35	61.80	66.64
Cross 2					
038	HP, HS, HY, HH	107.67	100.50	119.14	59.82
039	HP, HS, HY	81.08	101.98	104.77	62.42
040	HP, HS, HY	75.67	105.42	110.07	56.32
041	HP, HS	84.00	96.67	97.35	60.36
042	HP, HS	89.25	122.75	105.53	50.03
043	HP, HS, HY, HH	101.42	126.48	118.90	47.95
044	HP, HY	72.92	91.90	92.03	48.83
045	HP, HY	106.58	162.32	130.03	51.75
046	HP, HY	60.08	88.90	87.66	49.31
047	HP, HH	108.00	136.32	100.97	50.78
048	HS	72.92	91.90	92.03	92.03
049	HS	106.58	162.32	130.03	130.03
050	HS	60.08	88.90	87.66	87.66
051	HS	108.00	136.32	100.97	100.97
052	HY	74.50	88.90	91.64	51.59
053	HY	107.67	126.48	106.43	42.77
054	HY	60.25	91.90	101.49	36.29
055	HH	69.00	49.07	62.92	46.16
056	HH	81.00	57.73	41.14	29.70
057	HH	71.50	90.90	87.77	45.24
058	HH	99.67	126.65	118.99	46.41
059	HH	50.67	63.57	51.56	36.90
060	HH	87.35	136.32	100.97	47.89
061	HH	69.25	97.98	104.30	69.64
062	LP, LS, LY, LH	60.58	75.23	69.65	46.11
063	LP, LS, LY, LH	40.08	49.07	62.92	53.21
064	LP, LS, LY	32.92	67.73	69.48	54.82
065	LP, LS	71.00	80.42	87.90	51.66

Appendix-I Contd...

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
066	LP, LS, LY	74.50	80.92	91.64	54.87
067	LP, LS	42.92	58.57	47.66	39.95
068	LP, LS, LY	60.25	78.50	68.33	50.57
069	LP, LS, LY	50.67	57.33	55.28	43.09
070	LP	64.25	80.83	66.20	47.16
071	LP, LS	91.08	112.00	101.49	51.54
072	LS	64.25	80.83	66.20	47.16
073	LY	32.92	96.67	62.92	43.10
074	LY	60.08	80.92	87.66	52.62
075	LY	106.58	112.00	118.90	66.87
076	LY	108.00	122.75	100.97	47.79
077	LH	32.92	93.67	86.55	64.48
078	LH	64.08	82.92	95.24	58.35
079	LH	104.08	92.50	109.34	64.01
080	LH	72.92	78.50	68.33	50.57
081	LH	47.92	57.33	55.28	43.09
082	LH	108.00	120.85	105.30	52.15
083	LH	76.08	85.83	69.12	43.64
084	LH	104.58	112.00	104.03	53.68
Cross 3					
085	HP, HY	95.58	107.65	157.68	54.92
086	HP, HS, HY	33.75	57.90	97.78	53.58
087	HP, HY	29.17	43.43	81.54	46.67
088	HP, HY	58.25	84.90	103.27	69.57
089	HP, HS	90.50	126.40	171.81	68.55
090	HP, HS, HY	64.33	83.57	126.69	71.93
091	HP	86.08	114.07	181.69	75.03
092	HP, HY	42.67	58.75	68.56	61.71
093	HP, HS, HY	60.33	66.32	111.68	54.11
094	HP, HY,	56.17	70.65	90.93	59.77
095	HS	81.33	84.48	93.66	48.25
096	HS	65.83	79.73	81.54	38.84
097	HS	51.42	64.23	103.27	68.55
098	HS	45.75	68.73	181.69	136.11
099	HS	56.64	87.28	68.56	52.08

Appendix-I Contd...

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
100	HS	64.92	103.32	90.93	38.31
101	HY	94.50	130.40	177.33	63.16
102	HY	88.75	116.73	185.93	58.62
103	HH	98.08	110.65	166.68	59.29
104	HH	38.25	62.90	110.14	46.56
105	HH	23.03	29.48	59.75	27.71
106	HH	64.95	91.60	112.30	69.36
107	HH	95.62	131.52	184.05	62.70
108	HH	66.33	85.57	127.23	53.87
109	HH	89.40	117.69	191.65	59.68
110	HH	50.33	66.69	82.49	58.41,
111	HH	56.18	62.16	102.59	52.99
112	HH	75.50	95.00	91.04	54.81
113	LP, LS, LY, LH	64.33	86.23	126.46	42.36
114	LP, LS, LY, LH	81.33	84.48	110.72	57.05
115	LP, LY, LH,	56.50	73.82	97.11	58.88
116	LP	65.83	79.73	95.70	45.39
117	LP, LS, LY, LH	51.42	64.23	85.32	56.59
118	LP	49.08	60.15	84.52	52.18
119	LP, LS	45.75	68.73	95.56	71.59
120	LP, LS, LH	56.64	87.28	100.91	76.85
121	LP	47.14	77.48	93.66	64.29
122	LP, LS, LY	64.92	103.32	127.93	53.86
123	LS	29.17	43.43	95.70	54.14
124	LS	58.25	84.90	85.32	57.46
125	LS	42.92	58.57	83.81	70.16
126	LS	42.67	58.75	100.91	91.11
127	LY	55.83	69.73	83.81	45.59
128	LY	43.08	54.15	76.33	51.30
129	LY	42.75	65.73	91.38	71.34
130	LY	42.83	75.32	86.02	73.47
131	LY	38.50	70.82	85.63	65.23
132	LH	63.83	77.73	95.81	55.30
133	LH	50.08	61.15	85.33	68.45

Appendix-I Contd...

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
134	LH	41.50	73.82	94.63	78.72
135	LH	62.92	101.32	122.58	61.57
136	LH	53.52	70.80	83.31	58.83
Cross 4					
137	HP, HS, HY	63.86	105.07	85.06	47.25
138	HP, HS, HY	90.00	129.57	112.53	55.68
139	HP, HS, HY	65.25	96.82	68.54	47.22
140	HP, HS, HH	86.58	103.07	93.79	49.04
141	HP, HS	66.50	88.07	87.19	64.16
142	HP, HS	58.58	94.75	84.17	55.99
143	HP, HS	72.92	97.33	81.91	52.57
144	HP, HS, HY	68.67	115.17	75.57	37.58
145	HP, HY	81.25	97.42	94.81	38.37
146	HP, HS	106.17	164.42	126.26	47.65
147	HS	81.25	97.42	94.79	38.37
148	HY	70.50	74.00	79.11	57.12
149	HY	64.78	97.33	85.06	54.66
150	HY	90.00	89.67	112.53	71.73
151	HY	65.25	115.17	68.54	34.21
152	HY	66.50	164.42	87.19	32.80
153	HH	82.58	82.37	85.86	69.20
154	HH	61.17	69.25	63.83	57.04
155	HH	74.50	97.75	78.54	48.73
156	HH	71.50	74.00	79.11	57.12
157	HH	61.86	100.33	84.79	50.95
158	HH	90.00	87.67	112.52	73.99
159	HH	64.25	115.17	68.54	34.21
160	HH	73.33	82.00	68.40	33.11
161	HH	66.50	164.42	87.19	32.80
162	LP, LY, LH	58.75	84.17	61.06	45.16
163	LP, LY, LH	49.83	71.25	57.24	49.04
164	LP, LY	63.92	74.00	65.56	47.33
165	LP, LY, LH	69.75	89.67	76.09	48.50
166	LP, LY	59.50	85.00	76.43	35.37
167	LP, LY	80.58	95.98	84.03	48.05

Appendix-I Contd...

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
168	LP, LH	59.17	64.82	62.00	48.26
169	LP	72.33	85.23	78.45	48.93
170	LP, LY	70.50	86.65	79.11	44.16
171	LP, LY	70.83	83.23	67.81	42.97
172	LS	58.75	84.17	61.06	45.16
173	LS	49.83	71.25	57.24	49.04
174	LS	59.17	64.82	62.00	48.26
175	LS	72.33	85.23	78.45	48.93
176	LS	70.50	86.65	79.11	44.16
177	LS	70.83	83.23	67.81	42.97
178	LY	68.67	96.82	75.57	52.28
179	LY	81.25	103.07	94.80	49.48
180	LH	61.58	87.40	85.16	49.41
181	LH	75.92	103.07	81.91	50.52
182	LH	69.75	129.57	75.70	41.07
183	LH	85.25	102.07	100.80	54.15
184	LH	59.50	85.23	75.85	42.74
185	LH	105.28	88.07	126.25	92.12
Cross 5					
186	HP, HS, HH	85.33	113.37	121.86	43.41
187	HP, HS, HY, HH	82.50	121.95	136.58	50.56
188	HP, HS	75.83	110.28	146.07	46.69
189	HP, HY	62.67	72.70	102.88	42.46
190	HP, HY, HH	64.33	76.62	92.58	43.86
191	HP, HS, HY	82.50	86.53	103.57	48.11
192	HP, HS, HY	76.00	88.95	107.96	43.06
193	HP, HY, HH	73.50	92.20	94.09	40.41
194	HP, HS	78.33	96.62	145.70	42.77
195	HP, HS, HY	102.83	117.28	136.72	50.61
196	HS	62.67	72.70	102.88	42.46
197	HS	64.33	76.62	92.58	43.86
198	HS	73.50	92.20	94.09	40.41
199	HY	33.08	39.45	85.92	28.31
200	HY	73.50	92.20	89.91	40.41

Appendix-I Contd...

Progeny No.	Bases of plant selection in F_2	Pods/ plant	Seeds/ plant	Seed yield/ plot(g)	Harvest Index (%)
201	HY	64.33	76.62	90.25	43.86
202	HH	38.08	46.45	64.25	35.07
203	HH	61.33	70.12	78.88	40.26
204	HH	57.67	105.53	118.69	43.07
205	HH	87.50	126.95	140.48	48.35
206	HH	45.50	53.53	90.89	51.47
207	HH	100.83	120.28	136.71	47.73
208	LP	33.08	39.45	43.90	28.31
209	LP, LS, LY	57.33	68.12	78.77	43.83
210	LP, LY, LH	57.67	105.53	118.68	45.45
211	LP, LS, LY, LH	50.50	57.53	91.36	46.94
212	LP, LH	50.58	78.12	83.39	39.29
213	LP, LS	51.42	63.62	67.19	37.19
214	LP, LY, LH	60.58	68.37	79.16	32.47
215	LP, LS, LY, LH	41.33	49.53	69.45	33.28
216	LP, LS, LY, LH	53.50	71.03	90.47	42.18
217	LP, LY, LH	45.58	63.53	82.80	45.41
218	LS	57.67	105.53	118.68	45.45
219	LS	50.58	78.12	83.39	39.29
220	LS	60.58	68.37	79.16	32.47
221	LS	45.58	63.53	82.80	45.41
222	LY	85.33	113.37	127.34	43.41
223	LY	62.67	110.28	146.06	46.69
224	LH	45.58	70.12	86.06	37.14
225	LH	49.42	61.62	107.21	35.78
226	LH	62.67	72.70	102.88	42.46

HP = High pod number LP= Low pod number
HS = High seed number LS= Low seed number
HH= High harvest index LH= Low harvest index
HY= High yield LY= Low yield