RELATIONSHIPS AMONG THE F2 TO F6 GENERATIONS, AND EFFECT OF SPACING AND SELECTION IN F4 ON PERFORMANCE IN F5 GENERATION IN CHICKPEA

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

By
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College of Agriculture
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Rajendranagar, Hyderabad 500 030

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CERTIFICATE

Mr. Geletu Bejiga (G/Mariam) has satisfactorily prosecuted the course of research and that the thesis entitled "RELATIONSHIPS AMONG THE F2 TO F6 GENERATIONS, AND EFFECT OF SPACING AND SELECTION IN F4 ON PERFORMANCE IN F5 GENERATION IN CHICKPEA" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Date: 26-03-1987

Major Advisor

Dr. H. A. van Rheenen

Principal Chickpea Breeder

ICRISAT

CERTIFICATE

Mr. Geletu Bejiga (G/Mariam) has satisfactorily prosecuted the course of research and that the thesis entitled "RELATIONSHIPS AMONG THE F2 TO F6 GENERATIONS, AND EFFECT OF SPACING AND SELECTION IN F4 ON PERFORMANCE IN F5 GENERATION IN CHICKPEA" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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CERTIFICATE

This is to certify that the thesis entitled "RELATIONSHIPS AMONG THE F2 TO F6 GENERATIONS, AND EFFECT OF SPACING AND SELECTION IN F4 ON PERFORMANCE IN F5 GENERATION IN CHICKPEA" submitted in partial fulfilment of the requirements for the degree of "Doctor of Philosophy" in Genetics and Plant Breeding of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. Geletu Bejiga (G/Mariam) under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of investigation have been duly acknowledged by him.

Chairman of the Advisory Committee
Dr. H.A. van Rheenen
Principal Chickpea Breeder
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Thesis approved by the student Advisory Committee

Chairman — Dr. H.A. van Rheenen, Principal Chickpea Breeder, ICRISAT

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Member — Dr. Onkar Singh, Chickpea Breeder, ICRISAT

Member — Dr. Murari Singh, Statistician, ICRISAT

DECLARATION

I, Geletu Bejiga (G/Mariam) declare that the thesis entitled "RELATIONSHIPS AMONG THE F2 TO F6 GENERATIONS, AND EFFECT OF SPACING AND SELECTION IN F4 ON PERFORMANCE IN F5 GENERATION IN CHICKPEA" is a result of bonafide work done by me. I further certify that the thesis or any part thereof has not been published in any manner.

GELETU BEJIGA

Table of Contents

Page

1. INTRODUCTION.. 1

2. LITERATURE REVIEW.................................... 6
2.1. Relationships among generations........................ 6
2.2. Effect of spacing on the selection of high yielding lines............................ 23
2.3. Selection criteria................................ 27
2.3.1. Correlations in pure lines.................... 27
2.3.2. Correlations in segregating populations....... 36
2.3.3. Path coefficient analysis..................... 43

3. MATERIALS AND METHODS................................. 50

3.1. Parents and crosses................................ 50
3.2. Experiment I....................................... 52
3.2.1. Procedure for advancing generations........... 52
3.2.2. Crop husbandry................................ 52
3.2.3. Observations and characters studied........... 53
3.2.3.1.Days to 50% flowering................. 54
3.2.3.2.Days to maturity...................... 54
3.2.3.3.Plant height.......................... 54
3.2.3.4.Number of primary branches............ 54
3.2.3.5.Number of secondary branches.......... 54
3.2.3.6.Number of pods........................ 54
3.2.3.7.Number of seeds....................... 54
3.2.3.8.20-seed weight........................ 54
3.2.3.9.Yield per plant....................... 54
3.2.3.10.Yield per plot....................... 54

3.2.4. Analysis of variance.......................... 55
3.2.5. The variance for comparisons of treatment means 56
3.2.5.1.Error variance for the difference between means of two treatments appearing in the same block........... 56
3.2.5.2.Error variance for the difference between means of two treatments not appearing in the same block........... 56
3.2.5.3.Average variance of the differences... 57
3.2.5.4.Standard error of the mean............ 57
3.2.5.5.Relative efficiency................... 57
3.2.6. Correlations.................................. 57

3.3. Experiment II...................................... 58
3.3.1. Crop husbandary............................... 58
3.3.2. Selection procedures.......................... 58
3.3.3. Evaluation of F5 progenies.................... 59
3.3.4. Analysis of variance.......................... 60
3.3.5. Correlations.................................. 61
3.3.6. Path coefficient analysis..................... 62

Page

4. RESULTS.. 63

4.1. Experiment I.. 63
4.1.1. Mean yields....................................... 63
4.1.2. Correlations among F2 to F6 generations for mean yield.............................. 66
4.1.3. Correlations among F2 to F6 generations for different characters....................... 66
4.1.4. Correlations among yield components in different generations.............................. 70
4.1.4.1.F2 generation...................... 70
4.1.4.2.F3 generation...................... 71
4.1.4.3.F4 generation...................... 71
4.1.4.4.F5 generation...................... 74
4.1.4.5.F6 generation...................... 75

4.1.5. Correlation between yield and other characters for combined data of all generations......... 75

4.2. Experiment II....................................... 78
4.2.1. Means yields of the progenies selected from 9 crosses and two spacings.................... 78
4.2.2. Yield components of the single plant selections 88
4.2.2.1.Days to 50% flowering and maturity.... 88
4.2.2.2.Number of pods and seeds per plant.... 89
4.2.2.3.Number of primary and secondary branches 89
4.2.2.4.Yield per plant...................... 91
4.2.2.5.Seed weight.......................... 91

4.2.3. Analysis of variance for yield and other characters................................ 92
4.2.4. Correlation coefficients between yield and yield components.............................. 95
4.2.4.1.Correlation coefficients for combined data of two spacings................. 95
4.2.4.2.Correlation coefficients between yield and yield components in close spacing.. 97
4.2.4.3.Correlation coefficient between yield and yield components in wide spacing... 99
4.2.5. Path coefficient analysis.........................101

5. DISCUSSION AND CONCLUSION............................ 105

5.1. Experiment I.. 105
5.1.1. Mean yields....................................... 105
5.1.2. correlation coefficients among the yields of F2 to F6.................................. 108
5.1.3. Correlation coefficients among F2 to F6 for different characters...................... 114
5.1.4. Correlation coefficients among different characters.................................. 116

Page

5.2. Experiment II.. 120
5.2.1. Mean yields of the entries.................. 120
5.2.2. Correlation coefficients for yield and yield components............................ 127
5.2.3. Path coefficient analysis of yield components. 129

5.3. Conclusions.. 131

6. SUMMARY.. 133

LITERATURE CITED.. 136

VITA.. 149

List of Tables

Table No	Title	Page No
1	Crosses and their performance in the F3 yield trial of 1984	50
2	The parents involved in the crosses and their characters	51
3	Analysis of variance for lattice design in Experiment I	55
4	Analysis of variance for variables generated in Experiment II	61
5	Adjusted mean yield (kg/ha) of the nine crosses in the F2, F3, F4, F5 and F6 of chickpea	64
6	Correlations among the F2 to F6 generations based on the mean yields of the entires	67
7	Correlations among the F2 to F6 generations for different characters	68
8	Estimates of correlations among yield components in F2, F3, F4, F5 and F6 generations of chickpea	72
9	Associations among different characters in combined F2, F3, F4, F5 and F6 generations	76
10	Mean days to 50% flowering, maturity and yield (kg/ha) of different treatments in Experiment II	79
11	The means and ranges of yield components of F4 generation in close (30 cm x 10 cm) and wide (60 cm x 20 cm) spacings	90
12	Analysis of variance in F5 for days to 50% flowering maturity and yield for different entries in Experiment II.	93
13	Estimates of correlations between yield components and yield per plot for combined data of two spacings (30 cm x 10 cm and 60 cm x 20 cm)	96
14	Analysis of relationships between yield components and yield per plot in close spacing (30 cm x 10 cm)	98

Table No	Title	Page No
15	Analysis of the relationships between yield components and yield per plot in wide spacing (60 cm x 20 cm)	100
16	Path analysis of yield per plot versus days to 50% flowering and maturity, plant height, primary and secondary branches, pods, seeds, 20-seed weight and yield/plant for combined spacings (30 cm x 10 cm and 60 cm x 20 cm).	102

AKNOWLEDGEMENT

I wish to acknowledge and express my sincere thanks to the International Development Research Centre (IDRC) for granting me scholarship for my PhD studies and financed all the aspects of my stay in India. I am also very grateful to Andhra Pradesh Agricultural University (APAU) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for permitting me to use their excellent facilities and guidance of their staff members.

I wish to record my special thanks to the members of my Advisory Committee for their valuable instruction, guidance and constructive criticism throughout the course of investigation and in preparation of this thesis. They are Dr. H.A. van Rheenen, Principal Chickpea Breeder, ICRISAT (Chairman), Dr. C.A. Jagdish, Professor and Head, Department of Genetics and Plant Breeding, APAU (Co-Chairman), Dr. Onkar Singh, Chickpea Breeder, ICRISAT (Member) and Dr. Murari Singh, Statistician, ICRISAT (Member).

I wish to express my sincere thank to Dr. Roger A. Kirkby, IDRC, Nairobi, East Africa for his deep interest, genuine assistance and recommendation to arrange this financial support. I wish to express my special thanks to Dr. D.L. Oswalt, Principal Training Officer, ICRISAT, and Dr. Melak Hail Mengesha, Leader, Genetics Resource Program, ICRISAT for their keen interest to arrange my PhD studies with ICRISAT and for their valuable guidance, encouragement and advice from time to time during my stay at ICRISAT. They are also acknowledged for reviewing this manuscript. I wish to extend my thanks to Dr. Barry Smithson (previous Principal Chickpea Breeder at ICRISAT) for his continued effort to arrange my studies with ICRISAT.

I wish to thank Dr. Y.L. Nene, Director, Legume Program, ICRISAT for his continued help and encouragement during my stay in India. I am also grateful to Dr. G.C. Hawtin, Associate Director, IDRC, Dr. M.C. Saxena, Leader, Food Legumes Improvement Program, ICARDA and Dr.K.B. Singh, Chickpea Breeder, ICARDA for their encouragement and moral support through their numerous letters.

I would like to express my special appreciation to Drs. M.V. Reddy, S.C. Sethi, C.L.L. Gowda and R.P.S. Pundir of ICRISAT for their kind assistance and moral support. Thanks are due also to all the workers in Chickpea Breeding sub-program and Training Office for their excellent contribution and assistance during my stay at ICRISAT. I am also grateful to all the staff members in Statistics Office, ICRISAT, for their help to analyze the data. I wish to express my sincere thanks to all the staff members of the Department of Genetics and Plant Breeding, APAU for their help and guidance. I am thankful to Mr.P.Chenchaiah for typing several drafts of this manuscript and making it ready as required. I am also grateful to all the scientists I have met and shared their experiences either at ICRISAT or during my educational trips in India.

I wish to express my special thanks once again to Dr. and Mrs. M.H Mengesha not only for their assistance, advice, and moral support but also for their keen interest to my family.

I am also very grateful to Mrs. Jean Oswalt and Mr. Reva thi Rao for their help to arrange school for my children.

I am happy to express my sincere thanks to my friends Amanuel Gorfu and tesfaye Hagos for their moral support and encouragement.

I am highly indebted to my parent, brothers, sisters, relatives and friends for their good wishes, moral support and encouragement through their numerous letters during the period of my endeavour. I thank many others who have directly or indirectly helped me in preparing this thesis.

Finally, I would like to express my sincere appreciation and gratitude to my wife, Alem Tsehai Desta not only for her encouragement, moral support and typing part of this thesis but also for her dedication to take care of my children who have undergone some inconvenience during my endeavour. I also wish to express my special appreciation to my children Henok and Jalele for devoting their enjoyable time.

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Title	:	Relationships among the F2 to F6 generations, and effect of spacing and selection in F4 on performance in F5 generation in chickpea.
Degree	:	Doctor of Philosophy
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University	:	Andhra Pradesh Agricultural University
Year	:	1987

ABSTRACT

Two experiments were conducted 1. to determine the relationships among the F2 to F6 generations; and 2. to study the effect of spacing and selection in the F4 on the performance of F5 progenies of chickpea.

The results showed that the F2 yield had a significant and positive correlation with the F3. This indicates that under this experimental conditions early generation yield testing at the F2 could have been used as a reliable predictor of the performances of the crosses at the F3 generation. Hence elimination of the poor yielding crosses can be achieved at the F2 to concentrate the efforts on the high yielding crosses at later generations. The mean yields of the F2 or F3 had no significant correlation with F4, F5 and F6 generations.

Correlations obtained among the F2 to F6 generations for all the characters studied showed significant positive associations among the F2 to F6 generations for days to 50% flowering, maturity and seed weight. This shows that prediction for these characters can be made from the F2 or F3 generation. Correlations for other characters like plant height, primary and secondary branches, number of pods per plant, number of seeds per plant and seed yield per plant were not significant,indicating that these characters are not stable from generation to generation even under the same environment.

Correlation studies between yield and yield components separately in F2, F3, F4, F5 and F6 revealed that all the characters studied except days to 50% flowering and maturity had significant positive associations with seed yield per plant. The correlation values between these characters and seed yield per plant increased with advanced generations up to F5 and then stablized.

Spacing had a significant effect on selection in F4 as measured by the performance of the progenies in the F5 generation. Selection from wide spacing gave advantages of 0-20% and 9-28% over random selection and selection from close spacing.

Correlation studies between yield and other characters in different spacings exhibited that yield per plant had a positive association with all the characters except for days to 50% flowering and maturity. Among these characters 20-seed weight had only significant association with seed yield per plot in F5 generations.

The path coefficient analysis showed that seed weight had the maximum direct contribution to the yield per plot. Therefore, seed weight could be used as selection criterion in F4 to predict the performance of the F5 progenies. Selection from wide spacing (60cm x 20cm) would be more efficient in chickpea improvement than selection from crop spacing (30cm x 10cm).

INTRODUCTION

1. INTRODUCTION

Plant breeding has helped to promote agricultural development and has caused significant yield increases and quality improvement in different crops. For instance, during 1970 to 1980 wheat, rice and corn yield increased by 22.6%, 18.7% and 31.6% respectively in the world whereas soybean and broadbean yield increased by 13.5% and 17.3% resepectively (Stoskopf, 1985). According to Solunkhe et, al (1986) the wheat production in India was 12.4 million tonnes in 1965 and reached 26.5 million tonnes in 1972 and 35 million tonnes in 1981. This was due to the development of high yielding varieties that are capable of responding to improved cultural practices. Similarly in the U.K., national average yields of wheat increased slowly over the first fifty years of this century from 2.1 to 3.0 tonnes per hectare but have since advanced more rapidly to 5.7 tonnes per hectare in 1980 (Cooper, 1982). Tisadle et al (1985) also reported that variety improvement alone led to a 79% increase in yield of hard red spring wheat while a 38 to 61% increase in yield was obtained from recent corn hybrids over those developed in 1930s in USA.

Quality improvement is also under way in several crops. Evan (1975) reported that toxic substances in many wild yams have been eliminated and bitterness is reduced in lupins, while the contents as components of special interest to man, such as sugar in beet and cane, oil in maize and oil and protein in peanuts and soybean have been significantly increased. He indicated that selection for increased sugar content in the roots of beets began early in the nineteeth century and resulted in gains from 6% to over 20% within hundred years. Conventional plant breeding methods have been effective in bringing about these improvements but efforts are still being made to develop more efficient breeding methods to overcome specific problems. For instance, the use of early generation yield data and statistics for the association of plant characters with yield have recently received much attention. Early generation yield testing may help a breeder to identify and eliminate poorly performing populations at an early stage and therefore can save time, land and other resources provided that there are significantly strong correlations between the early and more advanced generations. Briggs and Shebeski (1971) and De Paw and Shebeski(1973) reported positive relations between the yields of F3, F4 and F5 populations in wheat. According to them the three highest yielding F5 populations in spring wheat were derived from high yielding F3 lines. The correlation between the yields of F3 lines and F4 bulk means in wheat was 0.59** whereas for F3 line and F5 family mean yields expressed as a percentage of the control was 0.56*.

In chickpea, Dahiya et al (1983b) found positive and significant correlations between F2 and F3, F2 and F4 and F3 and F4 generations. Dahiya et al (1984) also reported that the F3 yield trial selection method resulted in significant yield increases over both random and visual selection. These results have also shown that visual selection and random selection were equally ineffective in the identification of high yielding lines. On the other hand, Mckenzie and Lambert (1961) concluded that F3 yield tests were of little value in predicting F6 yields in barley.

Knott (1972) carried out the F3 yield test in wheat and found that testing on a plot basis was more effective than on an individual plant basis, and expressing the yield of F3 lines as percentage of adjacent checks, following the moving average of check method, increased the efficiency of these tests. But Knott and Kumar (1975) found early generation yield testing of very little use in wheat. They concluded that reliable yield testing in wheat can be done only when a reasonable degree of homozygosity is reached.

The selection criteria vary from crop to crop depending upon the yield components and their contribution to grain yield. Some of these components have direct effect on the yield while others have indirect influence. Adhikari and Pandey (1982a) reported that seed yield per plant in chickpea had significant and positive correlation with pods per plant and primary and secondary branches per plant. Katiyar et al (1981) also indicated that pods per plant had the highest direct effect on yield of chickpea but overall positive correlation between pods per plant and seed yield was reduced by a high negative indirect effect of pods per plant on seed yield via seeds per pod. Similar associations were reported by Khan et al (1983). Salih (1982) found very little associations among seed size, the number of pods per plant, seeds per plant, and plant height in chickpea.

According to Pandya and Pandey (1980), seeds per plant had a positive and high association with number of pod per plant, number of branches and days to flowering and very little association with 100-seed weight, while plant height showed a negative correlation with seed yield. Such studies were carried out mainly with pure lines and similar information for segregating populations is limited. Ram et al (1980) studied the segregating populations in chickpea and reported that pods and seeds per plant consistently showed the highest positive direct effect on seed yield in F2 and F3 generations in all the crosses studied.

Chickpea is planted at a spacing of 30 cm between rows and 10 cm between plants in a row for yield testing. But selection of single plants at ICRISAT and elsewhere is done from populations or progenies planted at wider spacing (60 cm x 20 cm) and the following generations are evaluated for their performance in normal spacing (30 cm x 10 cm). The effects of such changes in spacing on the performance of selected plants in the subsequent generation needs to be determined.

Having surveyed the problem areas as described a study was proposed that had the following objectives:

1. to determine the relationships among the performances of F2 to F6 generations and their implications for chickpea improvement,

2. to determine the effect of different spacings on single plant selection in F4 populations on performance of F5 progenies,
3. to establish the associations of yield and yield components in segregating populations of chickpea; and
4. to establish criteria for single plant selection.

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Relationship among generations

The objectives of plant breeders are to develop varieties of high yielding ability, good quality and adaptation to different climatic environment and management systems (Cooper, 1982). To achieve these objectives breeders must be able to identify the most appropriate selection procedures for the improvement of his crop (cooper, 1982). The common breeding methods currently used in self pollinated crops are pure line selection, mass selection, backcross, pedigree and bulk population breeding (Allard, 1960). Where crossing is involved and segregating populations are grown, the latter three methods are applied. These classical breeding methods are most efficient in terms of genetic gain per generation and per unit of time and it may not be advisable to evaluate large numbers of segregating populations (Bisen et al, 1985a).

In most of the cereal crops like wheat, corn, and barley several breeding procedures have been adopted, which helped to achieve considerable success. According to Hartmann et al (1981), plant breeders have gone beyond just improving native plant and have created a new man-made cereal, triticale by hybridizing the ancient grains, wheat and rye, which will help feed millions of people, although it is now being used for animal feed. Information on breeding procedures in pulse crops are more limited. Among pulses much work has been done in soybean to identify efficient breeding methods to generate high yielding varieties. In chickpea, more studies to develop reliable breeding methods for high and stable yields are required.

Several researchers have compared different breeding methods to determine their efficiency in identifying high yielding lines in different crops. For instance, Torrie (1958) compared pedigree and bulk methods of breeding in soybean for isolating high yielding lines in F6 of six crosses and the results showed that the mean seed yields were similar for the two methods, with two exception in which the bulk lines showed superiority. The effectiveness of bulk and pedigree systems was also studied by Raeber and Weber (1953) who suggested testing populations in replicated trials in the F3 and subsequent generations and simultaneously selecting phenotypically superior plants grown in a space-planted nursery. They reported genic fixation for yield in the F4 generation as measured by the performance of F6 high and low yielding pedigree based on their yield rank in the F4 generation. The work of Virupakshappa (1984) also revealed that there was no significant difference for pods per plant between pedigree, bulk and single seed descent breeding methods in cowpea. He found bulk and single seed descent methods to be advantageous in case of low yielding x high yielding crosses. Another example is the work of Empig and Fehr (1971) where they compared 4 methods of generation advancing in bulk hybrid soybean populations, namely, single seed descent (SSD), restricted cross-bulk (mechanical harvesting of a small section of each plot), maturity-group bulk (MGB) and cross bulk. It was found that single seed descent, restricted cross-bulk and maturity-group bulk maintained a similar number of high yielding lines, about twice as many as cross-bulk method. When these methods were compared for the time required in obtaining samples for the next generation, cross bulk was the fastest followed by restricted cross-bulk, single seed descent and maturity-group bulk. Brim (1966) was in favour of the single seed descent method in soybean breeding because:

1. it requires less space;
2. time and effort in harvesting is considerably less as compared to other methods;
3. book keeping and note taking is easy since only pedigree and degree of inbreeding records are kept and hence less effort is required.
4. selection for characters of high heritability can be effectively practised.
5. several generations can be grown per year

Because of different experiences and research results different breeding procedures are followed by different breeders working on the same crop. In recent years, the early generation yield testing procedure has received much attention. Weiss et al (1947), Singh (1976), and Muehlbauer and Slinkard (1981) emphasized the importance of early-generation yield testing because it allows the rapid elimination of inferior segregates and thereby increases the probability of obtaining desirable combinations in the remaining populations. It was also believed that it expedites the final release of a variety by allowing testing of the source populations before homozygosity has been attained (Weiss et al, 1947). It was with this view that a working group on chickpea breeding at the International Workshop on Chickpea Improvement (ICRISAT, 1980) gave the following recommendations.

1. to expand testing early generation (F1 and F2) bulks at different sites.
2. to do cooperative screening of advanced generations.
3. to collect information on the efficiency of selection and breeding methods.

Hence, at ICRISAT F2 populations of the highest-yielding F1s were grown in replicated trials at several locations and the best F2s were tested in F3 trials at more locations to reject the poorly performing population at the F1, F2, and F3 generations (Smithson, 1985). Harrington (1940) and Sikka et al (1959) concluded from early generation testing of bulk populations of barley and wheat crosses that bulk tests in early segregating generations may be useful to discard the low-potential crosses. Similarly, Allard (1960) recommended selection for high yield in early generations which should probably be limited to truncated selection in which only the poorest lines are eliminated. This is because F3 or F4 performance, as measured in single trials has generally been a poor basis for predicting the yields of subsequent selections. However, trials conducted in more than one location have been moderately good for the purpose of prediction (Allard, 1960). Smith and Lambert (1968) conducted early generation yield tests in spring barley and measured the predictive value with respect to yield and kernel weight and the results showed that the predictions were generally useful and reliable. They also recommend the following procedure as an efficient method of breeding self-fertilized crops;

1. to make a relatively large number of crosses among adapted high-yielding parents,
2. to evaluate these crosses as bulk populations in the F2 and F3 generations and
3. to continue selection, pure lining and testing in the best 25% or 30% of the crosses. This procedure was believed to lower the probability of losing a high proportion of superior pure lines in the discarded crosses.

There were several other experiments conducted to ascertain whether early generation yield testing would be useful in predicting the performance of the advanced generations in different crops. But, the results obtained by Bartley and Weber (1952), Johnson et al (1955a), Flower and Heyne (1955), Mckenzie and Lambert (1961), Briggs and Shebeski (1971), De Pauw and Shebeski (1973), Boerma and Cooper (1975a), Cregan and Busch (1977) and others are inconclusive. Mckenzie and Lambert (1961) compared F3 lines and their related F6 lines in two barley crosses and the correlation was found to be positive (0.313 and 0.543). According to them testing of families in the F3 generation for yield and other characters gave a reliable index of the breeding potential and they felt that early generation testing is more likely to be useful in crosses where there is a wide range in the yield of the segregates, and that early generation yield testing will likely not be suited for crosses between varieties differing little in yield potential. The work of Cregan and Busch (1977) confirmed the advantage of the F2 bulk generation test and also revealed that F3 and perhaps later generation bulk trials would seem desirable to confirm F2 results and detect possible genotype x environment interactions which would interfere with effective selection. Their fear was that such a method may eliminate populations with lower mean yields but with larger variances and thus some crosses with the potential of producing extremely high-yielding lines may be discarded. The effectiveness of early generation testing was further confirmed by the results obtained by Johnson et al (1955b) for characters such as a long fruiting period, lateness, heavy seed, resistantce to shattering, and high oil content in soybean.

The report of Boerma and Cooper (1975a) did not agree with the results obtained by Briggs and Shebeski (1971), De Pauw and Shebeski (1973) and Cregan and Busch (1977) since their findings suggested that the selection of pure lines in soybean is more successful than the selection of a heterogeneous F2 or F3 population by early generations yield testing. This was further supported by the work of Flower and Heyne (1955) who reported that the yield of early generation bulked crosses was of no value for predicting the yield of pure line selections in hard red winter wheat. This was mainly attributed to the inablity of the early generation yield testing to classify the crosses according to their yield potential. They concluded that it was probably due to high year to year variation in relative yield or inadequate technique for measuring yield. However, these were also opposed to the results obtained by Leffel and Hanson (1961), Voigt and Weber (1960) and Boerma and Cooper (1975b) who were strongly in favour of early generation yield testing. Leffel and Hanson (1961), concluded that the performances of the parents and their crosses in early bulk generations were reliable predictors of the performance of lines obtained from the crosses in the F3 generations in soybean. According to them, the reasons for many failures to identify high yielding progenies in early generations are: (1) Genotype-environment interaction, (2) inadequate testing in time and space, (3) Heterosis attributable to epistatic or dominance effects which is not maintained in pure lines, (4) heterozygosity and heterogeneity of genotypes within progenies and (5) interplant and interplot competition. Voigt and Weber (1960) conducted replicated yield trials in the F4 generation from F3 families of five soybean crosses and produced lines significantly higher in yield in the F5 generation compared with previously non - yield -tested lines selected by standard bulk and pedigree breeding methods. The lines selected by the early-generation method were also similar in maturity and height and superior or equal in lodging resistance to those selected by the bulk and pedigree methods of breeding. O'Brien et al (1978) concluded that the effectiveness of early-generation selection depends on the relative amount of environmental variation attributes to generation means and on the relative amount of non-additive genetic variation. The genotype x environment interaction will tend to reduce the correlation between generations. Their findings showed that the differences in yielding ability of F3 lines identified by replicated yield testing persisted over generations in only two of the four crosses. The observed differences in F3 yield tests could be attributed partly to genetic differences that will persist over generations and partly to genetic differences that are expressed only under the environmental conditions peculiar to the F3 yield test. The cross prediction was effective in identifying the best crosses in terms of the likelihood of finding inbred lines of spring barley that transgress the parental range for one or more characters by using F3 family analysis (Tapsell and Thomas, 1986). They suggested that best crosses could then be advanced towards homozygosity and more resources could be adopted to the better crosses. The same experiment, showed that early generation selection for reduced height had been effective as no lines were found taller than the tallest parents. But, the early generation selection for reduced height resulted in indirect selection against high yield and hence none of the selected lines were found to exceed the higher yielding parent. All possible cross combinations for seven varieties of wheat in generations F1-F5 were evaluated by Bhullar et al (1977) and the results obtained showed that the F2 yield data could be reliably used for identifying the high yield potential crosses while the F1 data appeared to be of limited value for predicting yield in subsequent generations. Early generation testing for inbred performance was also reported to be effective for all yield and quality traits in pickling cucumber, (Rubino and Wehner 1986). However, Welsh (1981) reviewed most of the work on early generation yield testing and found no clear-cut answer with respect to the usefulness of bulk yield testing for the ultimate selection of superior genotypes. According to him if the heritability is low at a high degree of environmental interaction, the value of the test is to be low since the environment can vary extensively from year to year which will result in erroneous selection decisions based on abnormal situations; another weakness is that tests are based on the mean value and do not provide the range and distribution pattern within each population. In populations discarded on their mean values, low frequency of high yielding individuals may be lost because of a high proportion of poor individuals pulls the mean down. If each population has approximately the same distribution pattern, then the test could be valid in identifying crosses with good probabilities for containing high performance selections; a third weakness is that some superior genotypes will only express their potential in pure stands but may be suppressed in genotypes mixtures.

Knott (1972) used F2 plants from eight wheat crosses which were accurately spaced in a uniform block of land. The F3 lines from selected and unselected F2 plants were yield tested and the results showed that selection had had a statistically significant effect. Hence, he suggested to use early generation yield testing on plots rather than individual plants. He also indicated that the yield of F3 lines expressed as either a percentage of adjacent checks or as a percentage of a moving average increased the efficiency of the test. Similarly, Knott and Kumar (1975), Dahiya et al (1984), Bisen et al (1984), Boerma and Cooper (1975c) and Bisen et al (1985b) compared the efficiency of early generation bulk test with other breeding methods to identify high yielding lines in different crops. Among these, the results obtained by Knott and Kumar (1975) in wheat indicated that the single seed descent method was more efficient than early generation yield testing. The best procedure proposed by Knott and Kumar (1975) was to minimize or eliminate yield testing in early generations and concentrate on it in later generations when reasonable homozygozity has been attained and reliable yield testing can be done. Similar procedures were recommended by Lupton and Whitehouse (1957) for characters as yield and grain quality in self pollinated cereals. Their report also indicated that selection in the early generations should be restricted to characters which are highly heritable and have therefore a high efficiency in selection. Boerma and Cooper (1975c) found single seed descent procedure to be most efficient because it required less selection effort than early generation yield testing and pedigree procedures, allowed 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. However, their results did not oppose the use of early-generation yield testing for further testing or the use of pedigree selection procedures to study the segregation of simply - inherited traits. The single seed descent procedure did not prove to be advantageous in cowpea (Ntare et al, 1984) and in chickpea (Bisen and Singh, 1983, Bisen et al 1984, 1985a, 1985b). Bisen et al (1985a) suggested that selection for seed size bulk (SSB) procedure proved to have advantage over other methods (single seed descent (SSD) and yield bulk (YB)) of selection aimed at the genetic improvement of chickpea for seed yield and also for consumers preference. The results showed that the SSB procedure was consistent in varying environments (different fertility levels and spacings) as compared to YB and SSD procedures (Bisen and Singh, 1983). Significant interaction was noted for crosses with breeding methods (Bisen et al, 1984). Compared to other breeding procedures, Bisen (1985b) showed that SSD populations would face the problem of genetic drift in the F3 and F4 and may result in depletion of desirable alleles while the superiority of the SSB method could be due to large seeded selections contributing a higher proportion of vigour in the next generation and increase gene frequencies for seed size in the desirable direction. However, he indicated that ultimately the seed size selection procedure was not efficient due to the following limitations: (1) after the optimum level of seed size is obtained seed size and seed yield show negative correlations in chickpea and (2) a decrease in the variability of seed size will occur during the continous selection process which may not give further scope for selection .

Chaudhary et al (1978) studied selection efficiency in chickpea based on heterosis, combining ability and early generation testing. Their findings indicated that selection of a cross for its breeding potential should be based on combining ability of the parents as well as on the relative F1 and F2 performance of the heterotic combinations with low inbreeding depression. Auckland and Singh (1977) also claimed to predict the future yield advance from the performance of early generations (F2 and F3). This was further confirmed by the findings of Dahiya et al (1983b), Dahiya et al (1984), and Dahiya et al (1986). Dahiya et al (1983b) grew the F2 in 1979/80, F3 in 1980/81 and F4 in 1981/82 in replicated trials. Though there were effects of genotype x environment interaction on relative yield across seasons, the results revealed that the seed yield of early generations in replicated tests were good indications of cross performance, and at least be useful as a basis for rejection of poor populations. They also reported considerable switching between the high and medium and between medium and low groups while there was no switching between high and poor yielders. They also reported that a cross F-61 x T-3 ranked first in F2, F3 and F4 at Hisar. The reason could be due to slow change in the population structure, since a population handled as a bulk for a few generations changes very slowly unless there is a high degree of selection pressure eliminating the poor competitors (Empig and Fehr, 1971). Such stagnation occurs specially for quantitatively inherited traits, where significant shifts in the mean do not usually occur until about 15th generation (Suneson 1956). When the efficiency of early generation yield testing, visual selection and random selection in chickpea was compared by Dahiya et al (1984), the high yielding population gave the highest yield in the next generation over the other populations. It was also found that selection of the highest yielding F3 lines resulted in a significant seed yield increase over both random and visual selection. But both random and visual selections were equally ineffective. Selection based on early generation yield testing can be improved by using experimental designs that minimize the environmental variablity (Dahiya et al, 1986).

Virupakshappa (1984) estimated inter-generation correlations in two crosses of cowpea in F2-F3, F3-F4 and F5-F6 generations and found significant inter-generation correlations in any of the cases for yield. On the other hand, Ntare et al (1984) reported that the differences in yielding ability of F3 lines of two cowpea crosses persisted over generations indicating that selection was effective. This was further confirmed by the highly significant correlations between F3 yields and those of later generations which ranged from $r = 0.51^{**}$ to 0.85^{**}. Caldwell and Weber (1965) reported that yield performance alone as criterion for selection was more efficient than an average index selection and only slightly inferior to a specific index selection in soybean. In wheat, Whan et al (1981) planted all the generations from F2 to F5 together in one season so that the results were not influenced by seasonal differences. The correlations ranged from $r = 0.51^{**}$ for the F2 line/F3 mean comparison to $r = 0.68^{**}$ for the F3 line/F4 mean to $r = 0.78^{**}$ for the F4 line/F5 mean. Their observations revealed that the absence of replications, where single lines were grown as single plots, reduced the accuracy in the determination of the yield and could have lowered the correlations. The strategy proposed for oats by Sampson (1972) was to choose the top yielding progenies on the basis of early generation means and to follow by selecting superior lines within those top progenies. Nass (1979) indicated the importance of F1 yields in identifying high yielding lines in spring wheat crosses. The crosses identified as high yielding in F1 had significantly greater mean yields in F4 than those of low yielding F1's. The high yielding crosses had three to four times as many lines in the top 10% in F4 than did the low yielding crosses, and thus he recommended mid parental yield, F1 yield and F2 yield tests as a progressive set of screening tests for a given set of crosses to effectively maintain the superior ones in the breeding program. But Weiss et al (1947) found no relationship among the crosses of soybean when the degree of heterosis as expressed in F1 was compared with the mean yield of F5 selections, which were retained on the basis of general agronomic desirability. One of the crosses which was second poorest non heterotic expression over the higher yielding parent in the field, yielded a number of desirable F5 lines. From the results it appeared that bulk population tests were of little value in the prediction of potential yield or date of maturity, but gave reasonable accurate evaluation of crosses for lodging resistance and height in subsequent selections. This was attributed to differential response by crosses as reported for the bulk F2 to F5 generations tests for all characters studied.

The early generation testing procedure was not widely adopted (Fehr, 1978), because the number of superior progenies often was as high in low-yielding crosses as in high yielding ones. The procedure involves expensive yield tests which are used to evaluate F2 lines that are not sufficiently pure for use as cultivars and it also generally takes more time for developing a new cultivar than the single seed descent method. One notable point from the results obtained by Weiss et al (1947) is the lack of agreement between bulk population mean yield and mean yields of surviving F5 lines selected from the crosses. This was illustrated by one of the crosses of soybean which was second highest in average yield in the F2 to F5 bulk yield tests but contributed only two lines in F5, which were low in yield. On the other hand, another cross which was one of the poorest in yield in the bulk test produced its F5 selections that yielded among the best. They also noted that consistent lack of agreement between the performance of crosses in different generations tested in the same year, or the same generation tested in different years. Similarly, Rahman and Bahl (1986) obtained poor inter-generation associations in chickpea for pods per plant and grain yield. These non-significant associations were attributed to year and agronomic effects, including plant population which had pronounced effects on such associations. It was concluded that making selection for high yield or high pod number in early generations will be of no value since genetic differences are masked by genotype x environment interaction. The high estimates of inter-generation correlations between F3 and F4 and the consistency of these associations over the hybrids have shown the advantage of early generations selection at F3 for characters such as seed per pod, 100-seed weight and plant height in chickpea. The consistency of these associations was attributed to the high heritability of the characters.

Hamblin and Evans (1976) studied the relationship between the yield potential of phaseolus been crosses for several generations and obtained significant differences between crosses in all generations (F3 to F6), but the yield of reciprocal crosses did not show significant differences in any generation. According to them the early generation cross yields, including those of the F2 were effective in predicting the cross potential in all suceeding generations and years when grown at crop densities. These data also suggested that F2 crosses should be tested in bulk replicated yield trials at crop densities and preferably at more than one site along with controls, which could be the parental genotypes. All low yielding crosses according to this report should therefore be discarded so allowing the maximum of effort to be concentrated during the suceeeding generations on the more promising materials.

Davies et al (1985) recommended small plot (1m2) for conducting early generation yield tests (F3 to F5) in peas (P. sativum L.) and the later generations to be tested at a number of locations in larger plots (> 10m2. The seasonal influences can be excluded by growing all generations together in one season as recommended by Whan et al (1981). Hamblin and Evans (1976) also recommended the following points when one follows the early generation yield testing procedure:

1) On the average the predictions will be improved as the number of replicates in the generations increases. It is therefore important that assessments of early generations bulk cross yield are carried out in properly replicated yield trials and not just in large single plots.

2) Pests and diseases may cause severe losses in certain areas, seasons or genotypes. These losses may seriously confound the results obtained, so that there is little correlation over generations and years for the yields of the crosses. Varieties or crosses that are genetically low yielding, but which have a measure of resistance to pests and diseases, as might occur in the wild, primitive types, may perform better in stress situations than crosses with high yield potential but no resistance. It is therefore essential to control pests and diseases during early generation yield testing.

The efficiency of the early generation testing also depends on the accurate estimates of yielding ability and the relevant genetic, environmental and interaction components of variance (Singh, 1976). It also depends on the ability to distinguish differences between genotypes in early generations and the persistence of these differences in later generations (O'Brien et al, 1978). Therefore, a high correlation between the performance of the crosses selected in early generations and the performance of their progenies in later generations is a requirement for the success of the early generation yield testing procedure.

2.2 Effect of spacing on the selection of high yielding lines:

Spacing between plants is known to have an influence on the performance of crop varieties. It determines the growth and development of the plants and influences yield components which directly and indirectly affect the final yield. Such effects of spacing in chickpea were reported by Sen and Jana (1960), Saxena and Sheldrake (1980), Shaktawat and Sharma (1985) and Singh and Yadav (1985). The report of Sen and Jana (1960) showed different spacings had no effect on the height of the chickpea plant except for the lowest spacing which showed reduced height throughout the growth period. This report also indicated that the wider spacing gave more branching and consequently a greater number of pods which helped to increase the yield per plant. The closest spaced plants 12" x 3" had the lowest number of fruits, reduced seed weight and the highest percentage of seedless pods. Shaktawat and Sharma (1985), Singh and Yadav (1985) and Saxena and Sheldrake (1980) found that increasing rates of seeding significantly reduced the number of pods and grain yield per plant. Similar findings were reported by Hussein et al (1986) and Penaloza (1986) in lentil, Bishnoi and Phogot (1986) in pigeonpea, Qayyum et al (1983) in soybean. McVetty et al (1986) obtained lower seed and total dry matter yields but the highest seed weight, number of pods per plant and days to maturity when 50% of the recommended rate of sowing was used in faba bean. It was also observed that number of pods per plant and the seed weight decreased as the sowing rate increased. In lentil, increasing plant density caused a great reduction in branch number per plant, secondary branches being most affected (Penaloza, 1986). This report showed that at plant densities of 44, 88 and 420 plants per m2, the percentage of total pods on the secondary branches was 67, 50 and 15% respectively. Similarly, Hussein et al (1986) report indicated that the number of branches and pods per plant and seed weight per plant decreased as seeding rate increased in lentil. The variation in seed rate was not found to alter the seed weight in chickpea (Singh and Yadav, 1985). In chickpea, higher seed rates reduced grain yields per pod and increased weight (Shaktawat and Sharma, 1985) and also improved earliness provided the conditions did not promote extensive vegetative growth (van Der Maesen, 1972). This leads to less branches because the leaf canopy is closed sooner.

Since the importance of spacing (seed rate) has been realized, many experiments have been and are conducted to identify the optimum spacing (seed rate) for different crops under different environmental conditions. Sen and Jana (1960) found that the individual plant yield was highest when chickpeas were sown in the widest spacing. Van der Maesen (1972) reported a row spacing of 25-30 cm as optimum. Verma and Singh (1974) and Ram et al (1973) found 30 cm inter-row spacing significantly superior over 45 and 60 cm spacing. The 30 cm spacing between rows gave higher yields than the 45 cm spacing at four different planting dates (Ram et al 1973); widening beyond 30 cm registered a decline in yield. Saxena and Sheldrake (1980) observed that branching of a normal cultivar is automatically suppressed when it is grown at high population densities, and a normal branching type tailors itself into a non branching type. Similar responses were reported in soybean by Funnah and Matsebula (1985) and Qayyum et al (1983). Funnah and Matsebula (1985) found that grain yield/ha increased with increasing plant density, reached a peak at 60 cm x 5 cm and then started decreasing with furhter increase in plant density. The report of Qayyum et al (1983) on soybean also showed that a spacing of 60 cm produced significantly more branches per plant than the 30 cm spacing. Hamblin (1975) observed that crop density had a larger effect on both seed number and seed yield per plant than different nitrogen levels and competition of genotypes.

Bisen et al (1984) compared three breeding procedures single seed descent (SSD), yield bulk (YB) and seed size bulk (SSD) under two spacings and two fertility levels to identify the high yielding lines in chickpea. The varying spacings were not found to influence results of the breeding procedures, but the lowest number of primary branches per plant was recorded in SSB under both spacings and fertility levels. The results obtained by Bisen et al (1983, 1985a and 1985b) further confirmed that fertility and spacing have no influence on the efficiency of any selection procedure indicating that selection under any spacing environment is equally good. On the other hand, he reported that SSB and SSD procedures were influenced by the spacings for number of seeds per plant. The variation in the fertility levels showed significant differences for seed yield only while variation due to spacing showed significant differences for number of pods, number of seeds and hundred seed weight (Bisen et al, 1985a). The mean square due to spacings x breeding methods was significant for all the characters (number of pods and seeds per plant and hundred seed weight and seed yield). The interaction due to fertility levels x spacings was significant for all the characters while the cross x spacing interaction was also significant for number of seeds and hundred seed weight. Significant interaction variation due to spacings x locations was recorded for number of pods, number of seeds and seed yield. Sneep et al (1979) also emphasized the importance of selection for performance in dense populations rather than selection of single plants in spaced plantings.

2.3. Selection Criteria

Stable grain yield is the most important trait the plant breeder wants to improve. It is the final product of several contributory factors and their interactions. It is naturally a complex character of many other traits, which again have inter-relations among themselves. These inter-relations can be positive or negative. It is therefore important to determine such inter-dependence among these contributory characters which may facilitate the interpretation of results already obtained and provide the basis for planning more efficient breeding programs for the future.

Correlation coefficients show patterns of association among yield components and growth attributes, indicating what complexities determine yield. Most of the studies on associations between yield and yield components have been carried out on homozygous populations, but it is realized that these fixed genotypes have some limitations in extrapolating data to genotypes in segregating populations. Such studies are therefore to be conducted on both homozygous genotypes and heterozygous and heterogeneous populations to determine the important and stable character or characters on which selection is to be based.

2.3.1. Correlations in Pure Lines (Cultivars)

Information is available for chickpea which shows the relationships between yield and its components and also among components in pure line cultivars. The relationships studied among eight different characters in nine chickpea lines showed that high positive correlations exist between plant height and internode length, between number of days to flowering and number of nodes up to the first flower, between height at flower initiation and seed yield, between number of pods per plant and seed yield and between seed size and seed yield (Baluch and Soomro, 1968). Sharma et al (1969) also carried out studies on correlation between yield and other characters in chickpea and found out that yield was positively correlated with eight morphological characters in the 44 lines studied. It was highly correlated genotypically, phenotypically and environmentally with number of flowers, number of pods, number of branches, number of seeds per pod and 100-seed weight. Plant height and pod length were also found to exhibit high significant genotypic correlations with yield, whereas pod width revealed a positive but non-significant correlation with seed yield. Important traits registered by Gill and Brar (1980) include plant height, primary branches, days to flowering, pods per plant, days to maturity, seeds per pod, seed size, 100-seed weight, seed yield, protein and ascorbic acid content of the seed. These characters should be considered while making selection for yield and protein improvement. Yield and six components of yield were also studied by Sandhu and Singh (1970) on sixty lines from thirteen countries and the results obtained revealed that the expected genetic advance for 100-seed weight and pod number per plant was high. The seed yield was found to be positively correlated with the number of primary branches, secondary branches and pods per plant. The importance of these three characters was further confirmed by the results obtained by Rang et al (1980), Khorgade et al (1985), Setty et al (1977) and Singh et al (1978). The correlation and path analysis carried out by Singh et al (1978) on six yield components of 75 chickpea lines showed that a selection index based on high pod and primary branch number and a low secondary branch number should improve yield. The analysis of yield components by Adhikari and Pandey (1982a) in chickpea also emphasized the importance of number of pods per plant and both primary and secondary branches which were positively associated with seed yield. Partial correlation and regression studies of Khorgade et al (1985) revealed that 100-seed weight and number of branches per plant were the most important yield determiners. The selection indices studied by them indicated that the use of single character indices exhibited no higher efficiency than straight selection for yield alone except 100-seed weight. Setty et al (1977), Tyagi et al (1982), Shahi et al (1984) and Chowdhury and Khan (1974) observed a positive association of yield with 100-seed weight. Hundred seed weight was also found to be positively correlated with number of seeds per ten pods and secondary branches per plant (Chowdhry and Khan, 1974). On the other hand, Dobholkar (1973) and Raju et al (1978) obtained results which exhibited a negative correlation between seed yield and 100-seed weight, but a positive correlation between yield and number of pods per plant and seeds per pod. The results obtained by Dahiya et al (1983a) were not in favour of using 100-seed weight as a selection criterion since the varieties used were unstable for this character. According to Setty et al (1977), days to flowering and days to maturity showed a negative correlation with seed yield. This was further supported by the report of Salih (1982) which revealed the significant negative correlation between seed yield and days to 50% flowering and maturity and the positive correlation between yield and plant population at harvest indicating the importance of earliness and good plant stand for high seed yields. The work of Setty et al (1977) showed that seed yield had a positive correlation with number of branches, pods per plant, seeds per pod, pod yield and seed volume. The analysis of data collected on thirteen traits in 132 lines of chickpea showed that pods per plant and seeds per pod were among the important components (Rang et al, 1980). Tyagi et al (1982) and Shahi et al (1984) stressed the importance of pods per plant since it was significantly and positively correlated with seed yield per plant. They also noted that pods per plant had a positive association with number of primary and secondary branches, while seed protein exhibited a significant negative correlation with seed yield per plant, seed weight and plant height. Dobholkar (1973), observed that the number of pods per plant was positively correlated with number of seeds per pod.

Among the components studied by Adhikari and Pandey (1982a), plant height and node number between first and last pod exhibited a high negative genotypic correlation with the seed yield though the phenotypic correlations were non-significant. Hundred seed weight was found to have a significant and negative correlation with seeds per pod while it had a highly significant and positive correlation with plant height. This report also showed the highly significant and negative correlation (-0.95) between plant height and pods per plant, indicating that plant height and pods per plant can not be improved simultaneously. Significant negative correlation of plant height with number of pods per plant was observed in soybean while the association of plant height with seed yield per plant was positive (Sharma et al, 1983). Islam et al (1982) found the number of pods per plant and the seed weight to be important components of yield. They also obtained a negative relationship between seed yield and plant height as Adhikari and Pandey (1982a). Singh et al (1980) proposed to increase the number of pods per plant, the seed size, the number of seeds per pod and the number of plants per unit area in tall plant types of chickpea.

Dahiya et al (1976) conducted an experiment to identify physiologically efficient genotypes in chickpea and found no correlation between total plant weight and effective pod number. The results further indicated that in large-seeded types, the 100-seed weight contributed to an improved harvest index, whereas in small-seeded types the number of seeds per pod was important. The major characters contributing to yield in chickpea were, according to Govil et al (1980) vigorous growth, erect habit, early flowering but late maturing, numerous pods per secondary branch and per plant, numerous seeds per pod, resistance to Fusarium oxyporium f. sp. Ciceri and small and less wrinkled seeds. The number of pods per plant, flower color and seed color, which were positively correlated with seed yield, were negatively correlated with leaf characters, height, days to flowering, pod size, seed size and degree of seed wrinkling (Govil, 1980).

Khan et al (1983) studied the variability, inter-relationships and path coefficients for some characters in chickpea and found out the highest heritability values of 96% for number of pods per plant and 93% for number of primary branches. Other characters such as plant height, 100-seed weight and seed yield per plant exhibited 77%, 57% and 53%, respectively. The findings of Khorgade et al (1985) and Mohanty and Sahoo (1974) were similar to those of Khan et al (1983) indicating that several characters are not much affected by the environment. According to these results yield was positively and significantly associated with number of branches and number of pods per plant and thus these two characters are ideal for effective selection for seed yield.

In general, similar associations were reported for other pulse crops such as lentil, pea, soybean, green gram and black gram. For instance, a positive association between number of pods per plant and seed yield was observed in lentils (Tikka et al, 1973 and Narsinghani et al, 1978), soybeans (Sharma et al, 1983, and Malik and Singh, 1982), pigeonpea (Shoran, 1982) beans (Santos et al, 1983), lima bean (Lyman, 1984), mungbean (Gupta et al, 1983), black gram (Rani and Rao, 1981), green gram (Malik et al, 1982). Analysis of the components of yield done by Singh (1985) for peas showed that days to 50% flowering, days to maturity, plant height and number of primary branches per plant were positively associated with grain yield as well as with each other indicating their efficiency for evolving high yielding varieties. The number of primary and secondary branches was highly associated with seed yield in lentils (Dixit, 1974 and Tikka et al 1973). Hundred seed weight was also found to have a significant positive correlation with seed yield in green gram (Malik et al, 1982), pigeonpea (Shoran, 1982 and Sindhu et al, 1985), soybean (Malik and Singh, 1982) and black gram (Rani and Rao, 1981). But Narsinghani et al (1978) obtained significant negative genotypic and phenotypic correlations of seed weight with seed yield, days to flowering and pods per plant. Sandhu et al (1980) stressed the importance of varieties with longer flowering durations and grain-filling period, ie flowering earlier and mature late will result in more productive varieties.

The stability assessment done by Santos et al (1983) for beans across seven locations showed that the only stable character was the number of pods per plant and thus this character appeared to be of value in selecting for stability of seed yield. Chandra's report (1968) has shown that plant characters of chickpea are affected by environment, particularly plant height and number of secondary branches. High genetic gains accompanied by the high heritability were observed for pods per plant, pod setting percentage, flowering duration and primary branches per plant while selection progress was expected to be greatest for seed weight and foliage colour. The association between various parameters suggested that selection for number of pods per plant and grain yield should lead to higher yields in favourable environments (Ramanujam and Gupta, 1973). These authors also suggested that an increase in number of pods per plant should be brought about by more pods per branch rather than by more branches per plant. The results obtained by Benjamini (1981) and Gupta and Ramanujam (1974) indicated that the number of pods per branch and the percentage of pods carrying two seeds instead of one, cause an increase in seed yield.

In summary, most of the results reported on correlation between yield and yield components have shown that yield is positively associated with the numbers of primary and secondary branches and pods per plant. Selection based on the number of branches, number of pods, number of seeds, volume and weight of seeds was suggested to be very important and reliable in improving the yield (Setty et al, 1977). The review made by Smithson et al (1985) showed that fruit number per plant has been significantly correlated with seed yield per plant in all of more than sixty cases reported, with correlation values ranging from 0.28 to 0.96. Also the number of seeds per plant was significantly and positively correlated with seed yield and fruit number per plant. Both primary and secondary branches play important roles since they are positively correlated with fruit number and yield per plant. For yield improvement in chickpea, Jain et al (1981) recommended to consider 100-seed weight, pods per plant, flowering period and harvest index in that order. The stability of yield was correlated with the stability of pod number and seeds per 100 grams. The partial regression analysis carried out by Sandhu and Singh (1970) confirmed the importance of pod number per plant which had the strongest influence on yield and indicated that the selection index based on this character accounted for 28% of variation in seed yield. Similar analysis done by Gupta et al (1972) exhibited that yield is mainly determined by the numbers of secondary branches, of pods per plant and of seeds per pod and a selection index based on these three characters was found to account for 80% of the total variation in yield. Kamatar (1985) studied heterosis and combining ability in chickpea and arrived at the conclusion that yield is mainly dependent on pod number per plant and suggested to follow procedures like biparental crosses and recurrent selection which he believed would result in high yielding lines. Pod number also determined yield per plant in pigeonpea (Singh et al, 1982), soybean (Marwan, 1983), and lentil (Tikka et al, 1973). This was mainly because it contains two primary components (Singh et al, 1982), the number of seeds per pod and size of seed. According Singh et al (1982) pods per plant had the maximum efficiency followed by height at maturity when selection was based on single characters in pigeonpea. Selection based on a combination of these two characters lead to higher efficiency (110%) and was superior to selection for yield alone. Similarly, Shahi et al (1984) found pods per plant and 100-seed weight to be the most important characters in chickpea. Yield alone was good indicator for expected genetic improvement and the expected gain from index selection was considered not worth since it involves intensive labour and efforts of data recording.

2.3.2. Correlations in segregating populations

As the selection criteria determine the efficiency of selection, it is essential to find out and consider the most important plant characters that influence yield. Many experiments have been conducted in field crops to obtain information on inter relationship between plant characters and yield. Such work has recently received attention in chickpea. For example, Dahiya et al (1986) compared the effectiveness of different selection criteria using the number of top yielding lines superior to the check. The results of this study in two crosses showed that the number of fruiting branches was the most effective selection criterion for increasing seed yield, and thus the F3 progenies superior for fruiting branches produced a higher frequency of top yielding F4 lines than the F3 progenies selected by other criteria. Similarly, selection based on pod number and seed weight was as effective as yield per se selection for obtaining superior yielding progenies. Naidu et al (1986) arrived at the same conclusion confirming that the number of fruiting branches is the best individual component for indirect selection to improve seed yield. Other investigators such as Tomar et al (1982), Ram et al (1980), Khan and Chaudhary (1975), Katiyar (1979), Jatasra et al (1978) Salimath and Bahl (1983) and Agrawal (1986) studied the relationships among yield and yield components. In most of the cases the seed yield was positively correlated with the number of pods per plant and the number of seeds per plant. In some cases the number of primary and secondary branches was reported to be important yield conponents for chickpea yield improvement. Ram et al (1980) studied six yield components in F2's and F3's of three crosses of chickpea and the results suggested that during selection attention must be given to the number of branches, pods and seeds per plant. They reported that pods per plant and seeds per plant were very effective measures of yield in chickpea. These two characters were also reported to have the maximum direct effect consistently in all the crosses used. Among the seven characters assessed in the F1 and F2 of 45 crosses, a negative correlation between seeds per pod and 250-seed weight and positive correlations between pods per plant and both seed yield and number of secondary branches per plant were detected in both generations (Katiyar, 1979). Similarly, Singh et al (1976) reported a negative correlation between 100-seed weight and number of seeds per pod. Seed number per plant was found to be negatively correlated with 100-seed weight (Mishra et al, 1974). Tomar et al (1982) observed positive associations between yield and number of pods per plant, number of seeds per pod, pod bearing branch length and number of secondary branches both in the F1 and F2 generation. But Khan and Chaudhary (1975) reported a negative association between yield and number of seeds per pod in the F3 generation of two crosses and their reciprocals. The importance of tertiary branches was also stressed by these authors. The number of pods per plant was significantly and positively correlated with all the morphological traits studied but seed yield showed a negative correlation with both number of seeds per pod and seed size. The number of seeds per pod and 100-seed weight had a negative correlation (Singh et al, 1976). The results of the study of F2 chickpea populations of crosses of small x small and large x large seeded parents showed that the number of pods per plant in all crosses and the number of branches per plant and the seed number per pod in association with the number of pods per plant in cross small x small and the 100-seed weight in large x large were suitable characters for selecting high yielding varieties. Katiyar and Singh (1978) studied such associations for seven characters in F1 and F2 generations of chickpea in a partial diallel among 15 parents and found that indirect selection for seed yield would be effective if based on 100-seed weight and number of secondary branches. The expected genetic advance was high for number of seeds per pod and 100-seed weight in both generations. They obtained the highest heritability estimates for these characters in both generations. Similarly, since Mandal and Bahl (1984) found seed weight and number of seeds per pods to be characters of moderately high to high heritability in three crosses, they concluded that early generation selection for these characters would be effective. Jatasra et al (1978) observed that seed yield has a negative correlation with number of days to flowering in F2 generations. They further noted that there was a positive association between number of pods per plant and number of seeds per plant while the number of pods per plant had a negative correlation with the number of seeds per pod. This shows that the number of pods per plant and the number of seeds per plant can be simultaneously improved, but this is impossible to achieve for the number of pods per plant and the number of seeds per pod. Analysis of variability made in four F3 populations revealed that the F3 population derived by selecting for seeds per pod provided slightly better scope for making further improvement in seed yield per plant (Salimath and Bahl, 1983). According to these data based on F2, predicted gains by direct selection were realized in F3 in case of pods per plant, seeds per pod and seed weight. The conclusion drawn from these data showed that selection for the characters mentioned in early generations of chickpea crosses would be useful for making genetic gains in seed yield. The correlations observed in the F2 between seed, total plant size and number of pods are useful to select desirable high yielding hybrids in subsequent generations (Khan, 1949).

In summary, most of the results obtained by Asawa and Tiwari (1976), Bajaj et al (1984), Asawa (1974), Asawa et al (1977), Agrawal (1986) and Mishra et al, (1974) revealed that the number of pods per plant and the number of seeds per plant are the most important traits for selection to improve yield in chickpea. Asawa (1974) proposed to give due consideration for seed weight. Kishore (1974) reported that stability of yield was correlated with the stability of pod number and seeds per 100 gm. The five crosses with the highest values in heterosis for yield per plant in chickpea were found to show significant positive heterosis for pod number per plant and number of primary branches per plant (Bhatt and Singh, 1980).

Several similar findings have been reported in other pulse crops. For instance, the number of pods per plant has been reported to have a highly significant correlation with seed yield per plant in pigeonpea (Singh et al, 1981), pea (Narsinghani et al, 1979), dry beans (Ghadri et al, 1984), Cowpea (Gowda, 1984), and soybean (Sharma, 1984). Radkov (1984) studied the yield components of three reciprocal french bean hybrids in the F2-F3 and found that seed yield per plant was significantly correlated with seed number per plant, 100-seed weight, pod length, and number of seeds per pod. It was concluded that selection should be performed for high pod and seed weight since these characters proved to be closely correlated with seed yield per unit area. Plant height was also reported to have high positive correlation with seed yield in F2 populations of soybean (Sharma, 1980, Sharma, 1984 and Malik and Singh, 1982) and F2's, F3's and F4's of pigeonpea (Awatade et al, 1980 and Singh et al, 1981). The different yield components in pigeonpea showed a favourable association with each other except for 100-seed weight with number of pods per plant (Singh et al, 1981). Gowda (1984) indicated that there were negative associations for pods per plant with 100-seed weight and seeds per pod with 100-seed weight in cowpea as was reported in chickpea by Katiyar (1979) and Singh et al (1976). Dani (1979) obtained a highly significant correlation between yield and number of inflorescences in pigeonpea.

Ghaderi et al (1984) grew twenty eight F2 populations from a half diallel of eight varieties of dry beans in compacted and non compacted soil and found an increase in 100 seed weight, but a decrease in yield and number of pods per plant and seed per pod in compacted soil. However, the yield remained positively correlated with number of pods per plant under both soil conditions. This indicates that the association between yield and number of pods is not influenced by the environment. It means that an improvement in one of these characters will result in an increase of the other. Sharma (1984) also evaluated four soybean crosses for genetic variability and interrelationships and found that the F2 population of one cross (Semmes X 8-3) gave the highest yield per plant. This was attributed to the high yielding recombinations consisted by this cross. Since the phenotypic and genotypic coefficient of variation, heritability and the expected genetic advance were the highest in this cross, it was concluded that selection of the segregates for higher seed yield per plant would be more effective in this cross than in the others. This also suggested that the same selection criteria may not be used for all crosses. This was further supported by the results obtained by Johnson et al (1955b) in two soybean populations. These findings demonstrated the opposite direction and differences in magnitude of the correlations between various pairs of characters in the two populations indicating distinct differences in the relationships between characters in the population. These authors also showed that there would be no reason to expect consistent associations between the same characters in other segregating populations of soybean. Sharma (1980) reported higher magnitude of genotypic correlation coefficients in soybean than the phenotypic ones, and this indicates that there is a strong inherent association between the various traits, but the phenotypic expression of the correlation is lessened under the influence of the environment. Johnson et al (1955b) also obtained slightly higher genotypic correlations than the phenotypic which could be due to the environmental effects as indicated by Sharma (1980).

Generally, yield is influenced by many factors, and particularly by the environment. Tikka et al (1973) were not in favour of the use of correlations for selection purposes because selection based on simple correlations without taking into consideration the interactions between component characters can be misleading. To demonstrate this, they took the number of secondary branches which showed a high positive correlation with grain yield in lentil but path - coefficient analysis revealed a negative direct contribution. The high positive association of this character with yield was attributed to its indirect contribution through pod number and number of primary branches. Another example was that of days to flowering which showed a high positive association with yield, but the direct contribution was negligible (0.033). This high positive correlation was attributed to its indirect contribution through pod number and number of primary branches. Therefore, the only two major characters which had the highest direct effect on yield were pod number and number of primary branches. This could be true for other pulse crops including chickpea. In lentil the emphasis on yield components as means of selecting improved lines has not been justified (Muehlbauer et al, 1985) because the components involved such as degree of branching and fruit number are influenced markedly by agronomy and environment (eg. spacing, available moisture, and time of planting) and so these components vary from year to year and location to location even for the same genotype. Their recommendation is that instead of committing limited resources to repetitive counting of yield components, breeders are advised to be aware of these limitations and to use procedures that not only recognize the importance of branching patterns and fruit set, but also avoid wasting time in collecting uninterpretable data.

2.3.3. Path coefficient analysis:

The interrelationship between yield and yield components and among yield components is usually determined by correlation method. The limitation of this method is that it shows only the associations but does not detect whether the association of one character with the yield is direct or through other characters. But path coefficient analysis provides an effective way of finding out direct and indirect sources of correlations (Khan et al, 1983). Singh and Paroda (1986) also showed that seeds per plant which had a positive correlation with yield had a negative direct effect on yield, whereas seed size which showed a negative correlation with yield, had a positive direct effect on it.

The path-coefficient analysis carried out for the economically important traits in chickpea have shown that these factors are interrelated and each factor influences the yield by a direct and an indirect contribution through other factors. Adhikari and Pandey (1982a) carried out both correlation and path analysis in chickpea and the results revealed that seed yield per plant had a significant and positive correlation with pods per plant and with primary and secondary branches per plant, but a high negative genotypic correlation with plant height and node number between first and last pod, though phenotypic correlation were found non-significant. Hundred seed weight had a highly significant and positive correlation with plant height, but was negatively correlated with seeds per pod. They obtained a highly significant negative correlation (-0.95) between plant height and pods. But the path-coefficient analysis indicated that days to complete flowering, pods per plant and 100-seed weight were the major direct contributors to seed yield. The number of secondary branches per plant which had a highly significant positive correlation with yield contributed negatively. This is contrary to the report of Khan et al (1983) which identified secondary branches as the major contributor to yield along with the number of pods. Hundred-seed weight contributed most directly to seed yield. However, its indirect negative influence through pods per plant and seeds per pod resulted in an overall non-significant correlation between them. These data suggested that since pods per plant is one of the major direct contributors which influence the seed yield negatively via 100-seed weight, another major direct contributor of yield, a balance between these characters with out affecting the total gain has to be made in selection. Pathak et al (1983), Gowda (1972), Bahl et al (1976), Katiyar et al (1981), Pandya and Pandey (1980) also reported these two characters as the major direct contributors to seed yield per plant. This was further confirmed by the work of Gowda and Pandya (1975), Asawa and Tiwari (1976) and Singh and Paroda

(1986). According to Asawa and Tiwari (1976), in all three populations studied in F3, number of seeds per plant and number of pods per plant had larger direct effects on seed yield than other characters while flowering time has shown negative effect. These findings showed that in all the three populations seeds per plant and 100 seeds weight showed positive effects consistently.

All the characters except number of pods and 100-seed weight have less direct effects on yield in chickpea; but their indirect effects via number of pods and 100-seed weight were large (Pandya and Pandey, 1980). The work of Chand et al (1975) showed that number of seeds per plant and 100-seed weight had a small direct effect but a large indirect effect on yield. The path analysis carried out by Ram et al (1980) in F2 and F3 crosses of chickpea have shown that numbers of pods and seeds per plant had consistently the maximum direct effect in all the crosses. Both characters had strong positive associations at F2 and F3 levels in all the three crosses. Smithson et al (1985) reviewed most of the work on chickpea and concluded that fruit and seed numbers have the largest direct effects on seed yield. They also indicated that correlated response may be expected when selection for yield is applied to any one of them. Number of seeds per pod was also found to have a high positive direct effect on yield (Tyagi et al, 1982; Bahl et al, 1976 and Jatasra et al, 1978). This was confirmed by Katiyar et al (1981) who reported its moderate direct effect and appreciable positive indirect effect via pods per plant. Seed number per pod and number of primary branches per plant were also found to exhibit the greatest positive direct effects on yield in F1 and F2, respectively (Katiyar, 1979).

The number of branches per plant exerted a negative direct effect, but its indirect effect via number of pods was positive (Pandya and Pandey, 1980). The path analysis done by Katiyar et al (1977) indicated that the number of branches per plant had the highest positive direct effect on grain yield and followed by the number of pods per plant and days to maturity. Katiyar (1979) and Tyagi et al (1982) also observed that the number of primary branches has the greatest positive direct effect on yield, while path-analysis done by Tomar et al (1982) and Sandhu and Singh (1972) confirmed that number of pods per plant and number of secondary branches were the most stable and important yield contributing traits. Sandhu and Singh (1972) recommended the use of a selection index (yield plus secondary branches) which was more efficient than selection for seed yield alone. Similarly, Ram et al (1980) proposed to make intensive selection for branches per plant, pods per plant and seeds per plant, since all of them ultimately influence yield directly and decisively. The number of branches per plant (Bahl et al, 1976) makes a substantial contribution directly towards pods per plant. The direct effects of numbers of primary and secondary branches were negligible, positive indirect effects via seed weight, number of days to flower and seeds per pod reduced the final correlation values (Katiyar et al, 1981). The positive association between secondary branches and yield was attributed to the highly positive and indirect effects of pods per plant, which showed a significant positive association with yield (Pathak et al, 1983). It was also due to a high positive direct contribution and indirect positive effect of pods per plant via number of secondary branches. The same results showed its indirect effect via harvest index and 100-seed weight as negative, whereas harvest index had positive and significant association with yield because of the strong positive effect of this character and indirect effect via number of secondary branches and pods per plant. According to these authors the presence of a positive residual effect suggested that besides the traits studied by them there are some other characters which contribute to grain yield in this crop. The discriminant function reported by Pathak et al, (1983) revealed a maximum gain (98%) by practising selection on the basis of pods per plant, harvest index and 100-seed weight over straight selection for yield. Selection progress was found to be greatest for seed weight and foliage color, while moderate progress was expected for plant height, seeds per pod, pods per plant and seed yield per plant (Adhikari and Pandey, 1982b).

The path analysis carried out by Phadnis et al (1970) supported selection of dwarf plants with a high number of pods and seeds per plant to improve yields in chickpea. Among seven characters studied in chickpea, Joshi (1972) noted that the number of pods per plant should be the main criterion for selection while the number of pod-bearing branches should also be considered. The association between number of seeds per pod and number of pods per plant depends mainly on the environment where the crop is grown (Singh, 1987 personal communication).

According to his explanation, chickpeas planted in a region with a short growing season such as at ICRISAT Center, Hyderabad usually have negative correlation between these two characters while in areas with a medium long growing season such as in Central India there is no correlation between these characters. Under conditions of a long growing season as for instance in northern India, the correlation is always positive. Days to flowering and maturity are always correlated negatively with yield per plant under Patancheru condition (Singh and Sethi, 1987, Personal communication).

As in chickpea, the path analyses done in soybean (Sharma, 1984 and Sharma et al, 1983), pigeonpea (Shoran, 1982, Sindhu et al 1985 and Dani, 1979), green gram (Malik et al, 1982), cowpea (Gowda, 1984), pea (Narsinghani et al, 1979) and lentil (Narsinghani et al, 1978) clearly revealed that number of pods per plant is one of the most important yield components on which selection should be based. Malik et al (1982) found for green gram that simultaneous selection for pods per plant, seeds per pod and seed weight is superior to straight selection and they calculated a maximum expected genetic advance. Number of inflorescences and number of seeds per plant (Dani, 1979) and number of clusters per plant and 100-seed weight (Awatade et al, 1980) were also found to be important characters next to number of pods per plant. Shoran (1982) obtained the highest direct effect of pods per plant accompanied by maximum indirect effects of other characters studied via pods per plant which established this character to be the most important component trait of seed yield in pigeonpea. Similarly, among all the characters studied by Sharma (1984), pods per plant was the only character with a significant direct and indirect contribution to seed yield per plant.

Most of the literatures cited on the correlation and path coefficient analysis clearly showed that number of pods per plant is the most important character in chickpea. Some reports indicated 100-seed weight as an important character contributing to yield, while some others mentioned number of seeds per pod, number of seeds and branches per plant as important characters.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Parents and Crosses

To study the relationship among the F2 to F6 generations, and to study the effect of spacing and selection in F4 on performance of F5 progenies, two experiments were carried out at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru, Hyderabad, India. These experiments involved nine crosses of short duration chickpea varieties, as listed below. These nine crosses were selected from 23 crosses based on their yield performance in the F3 generation at ICRISAT in 1984/85. The performance and ranking of the F3 populations are given below:

Table 1: Crosses and their performances in the F3 yield trial of 1984.

Cross	Yield(kg/ha)	Rank
RSG 44 x Phule G-7	2022	1
JG 1265 x 2375	1944	4
JG 1265 x Phule G-7	1932	5
Phule G-12 x 2E	1898	9
ICCC 6 x 2375	1846	11
ICCC 6 x JG-315	1844	12
2375 x JG-315	1540	22
Phule G-12 x 64-3	1488	23
64-3 x BDN9-3	1349	25

Source: Chickpea Breeding Program, ICRISAT.

The first three crosses were among the five top yielding crosses while Phule G-12 x 2E, ICCC 6 x 2375 and ICCC 6 x JG 315 ranked 9th, 11th and 12th respectively. The remaining three were the low yielding ones. The crosses with the rank of second, third, tenth and twenty fourth were left out because both parents are highly susceptible to the wilt disease caused by F. oxyporium spp. The ten parents involved in the crosses and their characteristics are given in Table 2.

Table 2: The parents involved in the crosses and their characters.

Parents		Characters
1. RSG 44	=	Medium duration, high yield and wide adaptation, double-podded and resistant to wilt.
2. Phule G-7	=	Medium duration, high yield, bold seed size.
3. JG 1265	=	Medium duration, high yield.
4. 2375	=	Short duration, high yield, resistant to wilt.
5. Phule G-12	=	Medium duration, high yield.
6. 2E	=	Short duration, high yield.
7. ICCC 6	=	Short duration, high yield not resistant to wilt.
8. JG 315	=	Medium duration, high yield, resistant to wilt.
9. 64-3	=	Short to medium duration, high yield and not resistant to wilt.
10.BDN9-3	=	Short duration, high yield and resistant to wilt.

Source: Chickpea Breeding Program and Genetic Resource Unit, ICRISAT.

3.2. Experiment I

3.2.1. Procedure for advancing generations

To study, the relationships among F2 to F6 generations of nine crosses, seeds of their F4 generation harvested in January 1985 were randomly divided into two lots and one lot was kept for planting in October 1986 while the remaining lot was sown on October 15, 1985 to produce F5 seeds. This nine crosses were selected based on their mean yield performance in 1984 F3 yield trial. In order to obtain F1 seeds the original parents were sown in September 1985, crosses were made and sufficient F1 seeds were obtained in January 1986. Fifty three randomly taken F1 seeds per cross were sown in greenhouse pots on February 2, 1986 to produce F2 seeds. In May 1986, the pods were continuously picked as they matured and air dried. Sixty F2 seeds harvested from the greenhouse in May 1986 and 60 seeds of each F1 and F5 obtained from 1985 September/October planted materials were randomly taken and sown on June 22, 1986 in plots of 4 rows (3m x 1.2 m) under a rainout shelter to generate F2, F3 and F6 seeds. In September 1986, all the plants per plot were harvested and the seeds were bulked to be used for the final evaluation.

3.2.2. Crop husbandry

The F2, F3, F4, F5 and F6 seeds of the nine crosses and four check varieties (Annegeri, K 850, BDN9-3 and 2375) were planted in a 7 x 7 partially balanced lattice design with four replications. The size of the plot was 4.8 m2(4m x 1.2 m) with 4 rows per plot. Spacings of 30 cm between rows and 10 cm between plants in a row were used. Since there was no rainfall in October (normal chickpea planting time at Patancheru), pre-planting furrow irrigation was given on October 18, 1986 and hence the soil was wet at planting time. The seeds were treated with Benlate T (wettable powder) at the rate of 3 gm per kilogram of seed. This consists of the following ingredients.

1. Benomyl (Methyl 1-(butycarbamoyl)-2-benzimidazolecarbamate=30%
2. Thiram (Tetramethylthiuramdisulfide = 30%
3. Inert ingredients = 40%

Two seeds were planted per hill to avoid a missing plants. The weak seedlings were thinned out on November 6, 1986 leaving only one plant per hill. Since germination was poor in Annegeri, the gaps were filled on the 16th day after initial planting. Just after germination some beetles were observed to cause damage to the seedlings. To control this pest Endosulfan 35% EC was sprayed on November 4, 1986 at the rate of 2 liters per hectare. This was followed by an incidence of pod borer (*H. armigera*) and hence the same insecticide (Endosulfan 35% EC) was sprayed at the rate of 2 liters per hectare on November 20 and 22 and December 24, 26, 30, 1986 and January 13, 1987. Several weedings were done during the growing season to keep the crop free of weeds. The second furrow irrigation was given just at flowering on November 25, 1986.

3.2.3. Observations and characters studied

Observations were recorded for days to 50% flowering and maturity on a plot basis while observations for other characters were recorded on five randomly selected plants per plot. These characters were:

3.2.3.1. Days to 50% flowering:

Number of days from sowing date to flowering of 50% of the plants in a plot.

3.2.3.2. Days to maturity:

Number of days from sowing date to maturity (all plants were ready for harvest).

3.2.3.3. Plant height:

The height of the plant measured in centimeters from the base of the plant to the tip of the tallest branch at maturity.

3.2.3.4. Number of primary branches:

The number of branches from the main stem counted at maturity.

3.2.3.5. Number of secondary branches:

The number of branches from primary branches counted at maturity.

3.2.3.6. Number of pods

The total number of pods per plant.

3.2.3.7. Number of seeds

The total number of seeds per plant.

3.2.3.8. 20-seed weight

The weight of 20 randomly selected seeds from the total seeds of a plant to the nearest 0.1 gram.

3.2.3.9. Yield per plant

The weight of the total seeds of a plant in grams.

3.2.3.10. Yield per plot

The mean seed weight of each treatment converted into kilograms per hectare.

Since spacing between plots was also 30 cm, the final grain yield was determined from all four rows per plot with an area of 4.2 m2(3.5 m x 1.2 m). The length of the plot was reduced to 3.5 m at harvest because 0.25 m was ignored from both ends of the plots to avoid effects from the pathways.

3.2.4. Analysis of variance

The analysis of variance was carried out for grain yield following the steps given by Gomez and Gomez (1984) and Cochran and Cox (1957) (Table 3). The F value, effective error mean square, coefficient of variation, standard error and efficiency of this design over a randomized complete block design were determined using the formula as stated in Table 3. The mean yield of each generation and mean yield of each entry across the generations were also determined.

Table 3: Analysis of variance for lattice design in experiment I

Source of variation	d.f.	Mean square(MS)
Replication	r-1	
Block (adj)	r(k-1)	
Treatment (Unadj)	k^2-1	
Intrablock error	(k-1)(rk-k-1)	
Treatment (adj)	k^2-1	
Total	rk^2-1	

Where r is the number of replications and k is the number of blocks/replication size. The statistics for testing the equality of treatment effects follows an F-distribution with k^2-1 and $(k-1)(rk-k-1)$ degrees of freedom when treatments have equal effects.

$$F = \frac{\text{Treatment (adj) MS}}{\text{Intra block error MS}}$$

The coefficient of variation (cv.) giving the precision of the trial is

$$CV = \frac{\sqrt{\text{Intra block error MS}}}{\text{Grand mean}} \times 100$$

3.2.5. *The variance for comparisons of treatment means.*

3.2.5.1. Error variance for the difference among means of two treatments appearing in the same block

$$= \frac{2E_e}{r} \{1+(r-1)\mu\}$$

where E_e is the mean square for intra-blocks error, r is replications.

$$\mu = \frac{(E_b - E_e)}{k(r-1)E_b}$$

where E_b is the mean square for blocks error,

k is number of blocks per replication.

3.2.5.2. Error variance for the difference between means of two treatments not appearing in the same block

$$\frac{2E_e}{r} (1+r\mu)$$

3.2.5.3. Average variance of the differences

$$= \frac{2E_e}{r} \{1 + \frac{rk\mu}{(k+1)}\}$$

3.2.5.4. Standard error of the mean = $\frac{\sqrt{\text{error variance of the difference}}}{2}$

3.2.5.5. Relative efficiency =

$$\left[\frac{\text{Block(adj)SS+Intrablock error SS}}{r(k-1)+(k-1)(rk-k-1)}\right]\left[\frac{100}{\text{error MS}}\right]$$

3.2.6. Correlations

Correlations were estimated among the F2 to F6 generations for the mean yields and other characters such as days to 50% flowering and maturity, plant height, numbers of primary and secondary branches, number of pods and number of seeds per plant, 20 seed weight and yield per plant. Similarly correlations among the yield components were estimated in each generation separately. Finally, the associations among different characters were computed from combined F2, F3, F4, F5 and F6 generations.

The correlation (r) values between two variables, X and Y were determined by the formula

$$r = \frac{(x_i-\bar{x})\ (y_i-\bar{y})}{\sqrt{(x_i-\bar{x})^2\ (y_i-\bar{y})^2}}$$

where (x_i, y_i) are the pairs of values on X and Y for the i^{th} unit (i = 1, ..., n) and $\bar{x}$, $\bar{y}$ are the means $\bar{x} = \frac{x_i}{\ }$,

$$\bar{y} = \frac{Y_i}{n} \quad \text{respectively}$$

3.3. Experiment II

3.3.1. Crop husbandry

To study the effect of different spacings on single plant selection in F4 populations and on the performance of F5 progenies and to establish the criteria of single plant selection in the F4 generation, the same nine F4 crosses used in Experiment I were sown on 13th October 1985 in two spacings (30 cm x 10 cm, and 60 cm x 20 cm). The split plot design with four replications was used. Equal number of seeds (320 seeds per plot) were used in the two spacings (30cm x 10 cm and 60 cm x 20 cm). While sowing, two seeds were used per hill and the third week after planting the weak seedlings were thinned out. Several weedings were given during the growing season of the crop. Two sprays were done in December 1985 at the rate of 2 liters of Endosulfan 35% EC per hectare to control pod borer (H. armigera).

3.3.2. Selection procedures

At maturity, 40 plants (10 plants per treatment in each replication) were selected from each spacing based on the number of branches and pods. This selection was done from two rows of 30 cm x 10 cm spacing and four rows of 60 cm x 20 cm spacing. The remaining two rows of 30 cm x 10 cm and four rows of 60 cm x 20 cm were left for random selection. However, before random selection was started there had been rain accompanied by winds which damaged the branches of the weak plants in close spacing (30 cm x 10 cm) and it was difficult to determine the number of branches and pods per plant. Hence, random selection was restricted to the wide spacing (60 cm x 20 cm) where the plants were relatively vigourous. Ten plants per treatment in each replication (forty plants per treatment) were selected. In the laboratory, the number of seeds, 20 seed weight and yield per plant were determined for all the plants regardless of selection methods. After all the characters were recorded for the selected plants, the 30 plants per cross which had the highest yield per plants, numbers of pods and seeds per plant were selected from the 40 plants initially selected from the field. Similarly, 30 plants were randomly selected from the initial 40 randomly picked plants. The seeds were kept in the cold storage from March to the end of August 1986. These seeds were treated with benalate T before they were planted in October 1986.

3.3.3. Evaluation of F5 progenies

Sowing was done on October 23, 1986 in a compact family block design (Panse and Sukhatme, 1978) with two replications. These treatments were randomly arranged as given by Panse and Sukhatme (1978). This experiment was planted at ICRISAT Center in field number BM-14B. They were sown in single row plots of 1.5 m length. A spacing of 30 cm between progeny rows and 10 cm between plants in a row was utilized. A spacing of 50 cm between blocks was used. This plot size was determined by the lowest number of seeds (15 seeds) available from some of the randomly selected plants. All selected plants based on the selection criteria were sown in two replications while seeds of randomly selected plants were only sown in one replication. To arrange the field plots systematically, the 30 randomly selected plants' progenies per family were divided randomly into two and thus 15 of them per treatment were randomized again along with the selected plants progenies from wide and close spacing within their families in one replication while the remaining 15 progenies were similarly randomized within their own families in the second replication. Another variety was planted on all sides of the experimental field to reduce border effects.

As in the experiment I (3.2) pre-planting furrow irrigation was given on October 18, 1986. By the time of planting (October 23, 1986) the soil was moist for good germination. The second furrow irrigation was given just at flowering on November 25, 1986. Several weedings were done during the crop growing season. Endosulfan 35% EC was sprayed at the rate of 2 liters per hectare on November 4, 1986 to control beetles which caused some damage to a few seedlings. A high population of pod borer was observed in this season, particularly after mid-December. To control this pest six sprays were made at the rate of 2 liters of Endosulfan 35% EC per hectare on November 20 and 22 and December 24, 26 and 30, 1986 and January 13, 1987.

3.3.4. Analysis of variance

Observations were made on days to 50% flowering, maturity, and seed yield. The analyses of variance for these characters were carried out to determine the differences among families, spacings and spacing x family interaction and within individual family. The differences between spacings, entries within close spacing (30 cm x 10 cm) and wide spacing (60 cm x 20 cm) and spacing vs check were also determined within an individual family (Table 4).

Table 4: Analysis of variance for variables generated in Experiment II.

Source of variation	d.f.	Mean square
Replication	r-1	
Family	f-1	
Error (family)	(r-1)(f-1)	
Within family	f(e-1)=fsℓ	
Spacing	s-1	
Spacing x family	(s-1)(f-1)	
Remainder	f(sl-s+1)	
Error (pooled)	(r-1)fsℓ	
<u>Within Individual family</u>		
Family 1:		
Between spacings (s=2)	s-1	
Entries within close spacing	ℓ-1	
Entries within wide spacing	ℓ-1	
Spacing vs check	1	
Error (family 1)	(r-1)sℓ	
.	.	
.	.	
.	.	
.	.	
.	.	
Family 9		
Between spacing s=2)	s-1	
Entries within close spacing	ℓ-1	
Entries within wide spacing	ℓ-1	
Spacing vs check	1	
Error (family 9)	(r-1)sℓ	

In experiment II, d.f. = degrees of freedom, f = 9 families, r = 2 replications, e = s x ℓ+1 entries within each family; ℓ = 30 lines selected from each of spacing, s = 2 spacings and there was one check,

3.3.5. <u>Correlations</u>

The observations made on single plants in 1985/86 and the grain yield per plot in 1986/87 were used to compute correlations and path coefficient analysis to determine criteria for single plant selection in the F4.

3.3.6. Path Coefficient Analysis

The direct effects of P variables x_1, x_2 ... X_p variable Y and the indirect effect of x_i on Y via x_j ($i \neq j$ = 1, 2 ... P) in a system of inter-related variables x_1, x_2... x_p and Y were obtained by decomposing correlation, corr (x_i, Y) = r (x_i, Y). Using the method of path analysis (Wright (1934), Kempthone (1973) and Singh and Chaudhary (1985)) the direct effects a_1, a_2... a_p of x_1....x_p respectively explaining Y were obtained by solving the equations

$$r\ (x_i,\ Y) = \sum_{j=1}^{a_p} a_i\ r\ (x_i,\ x_j) \text{ ---- } (1)$$

i = 1,2, ... p;

Where $r\ (x_i,\ x_j)$ correlation between x_i and x_j.

Note that $r(x_i, x_j) = 1$.

These simultaneous equations in (1) were solved by inverting the correlation matrix of x_1... x_p. Thus the direct effect of x_i on Y is a_i and the indirect effect of x_i on Y, via x_j = $r\ (x_i,\ x_j)$.

RESULTS

4. RESULTS

4.1. Experiment I

An experiment was conducted to determine the relationships among F2 to F6 generations of the crosses in chickpea.

4.1.1. Mean yields

There were significant differences among the mean yields of the treatments. The F3 of RSG 44 x Phule G-7 and some other crosses had significantly higher mean yields than the three of the check varieties but not K 850 (Table 5). There were no significant differences among the mean yields of the crosses in the F2 and F6 generations while there were significant differences among the mean yields of the crosses in the F3, F4 and F5 generations (Table 5). There were no crosses that showed significantly higher mean yield than the check variety K 850. The lowest yield was obtained from Annegeri (check variety). When the mean yields of the crosses over the five generations were compared based on their ranks, RSG 44 x Phule G-7 was first and 2375 x JG 315 was second. The cross JG 1265 x Phule G-7 was found to be the third in rank. The mean yields of these crosses were significantly higher than the mean yield of the cross JG 1265 x 2375. Based on their mean yield performance, the crosses RSG 44 x Phule G-7, 2375 x JG 315 and JG 1265 x Phule G-7 were considered as the three top yielding entries while ICCC 6 x 2375, ICCC 6 x JG 315 and JG 1265 x 2375 were found to be the poor performing crosses. However, there were no statistically significant differences among the mean yields of RSG 44 x Phule

Table 5: Adjusted mean yield (kg/ha) of the nine crosses in the F2, F3, F4, F5 and F6 of chickpea.

Entry	F2	F3	F4	F5	F6	Mean of crosses	Present rank	Rank of 1984 F3 yield trial
RSG 44xPhule G-7	2539	2605	2361	2232	2428	2433	1	1(1)
JG 1265x2375	2413	2335	2065	2084	2428	2265	9	4(2)
JG 1265xPhuleG-7	2444	2548	2187	2300	2516	2399	3	5(3)
Phule G-12x2E	2379	2483	2341	2244	2298	2349	5	9(4)
ICCC6x2375	2430	2272	2244	2172	2327	2289	7	11(5)
ICCC6xJG315	2273	2339	2281	2083	2455	2286	8	12(6)
2375xJG315	2488	2515	2211	2477	2375	2413	2	22(7)
Phule G-12x64-3	2295	2221	2352	2367	2394	2326	6	23(8)
64-3xBDN9-3	2479	2314	2277	2427	2338	2367	4	25(9)
Annegeri(check)						2044		
K-850(check)						2593		
BDN9-3(check)						2138		
2375(check)						2313		
Mean of generations	2416	2404	2256	2265	2395			
Rank	1	2	5	4	3			

Standard error (SE)± = 101.6

F-value calculated (VR) 1.78**

Effective error mean square (EMS) 41253.8125

LSD (5% for testing the significance of all 49 entries (comprising of five generations, 9 crosses and 4 checks) = 287.4

LSD (5%) for comparing crosses = 128.5.

LSD (5%) for comparing generations = 95.8.

Coefficient of variation (CV%) 8.7

% Efficiency of design over RBD 103.0

G-7, JG 1265 x Phule G-7, Phule G-12 x 2E, 2375 x JG 315, Phule G-12 x 64-3 and 64-3 x BDN 9-3 (Table 5). The cross RSG44 x Phule G-7, 2375 x JG 315 and JG 1265 x Phule G-7 gave higher yield in F2 and F3. But the crosses RSG44 x Phule G-7, Phule G-12 x 64-3 and Phule G-12 x 2E ranked first, second and third in F4. Among these, RSG44 x Phule G-7 had only significantly higher mean yield than JG 1265 x 2375, JG 1265 x Phule G-7 and 2375 x JG 315 in this generation (Table 5). The crosses 2375 x JG 315, 64-3 x BDN9-3 and Phule G-12 x 64-3 which were the poor yielders in 1984 F3 yield trial ranked first, second and third in F5. The cross 2375 x JG 315 had significantly higher mean yield than the other crosses except Phule G-12 x 64-3 and 64-3 x BDN 9-3. This cross had low yield than a cross JG 1265 x Phule G-7 in F6 (Table 5). The mean yields of different generations were compared based on their ranks and the F2 was found to be first and followed by F3 and F6 generations. There were no statistically significant differences among the mean yields of these three generations. The lowest mean yield was obtained from F4 generation (Table 5). The mean yields of F2, F3 and F6 were significantly higher than the mean yields of F4 and F5 generations. Switching of the rank was observed for all the crosses in different generations except in case of RSG 44 x Phule G-7 which ranked consistently first in F2, F3 and F4 generations. The crosses JG 1265 x 2375, JG 1265 x Phule G-7, ICCC 6 x JG 315 and 2375 x JG 315 had significant differences among the mean yields of their own progenies in different generations (Table 5). The remaining crosses had no significant differences among the mean yields of their progenies in different generations.

4.1.2. Correlations among F2 to F6 generations for mean yield

Correlation analyses were carried out to determine the associations among F2 to F6 generation and the results showed that there was a significant and positive association (0.6743*) between the mean yields of the F2 and F3 generations (Table 6). There were no significant correlations between F2 and F4, F2 and F5, and F2 and F6 generations. There were no significant correlations between F3 and F4 and F5 and F6 generations. Generally, significant and positive association existed only between mean yields of F2 and F3 generation, whereas the positive and negative correlations among the other generations were not statistically significant.

4.1.3. Correlations among F2 to F6 generation for different characters

Similar analysis was made to determine the relationships within the F2 to F6 generations for the characters such as days to 50% flowering and maturity, plant height, numbers of primary and secondary branches, pods, seed number and yield per plant and 20 seed weight. Highly significant and positive correlations of F2 with F3 and F4 generations for the days to 50% flowering and 20 seed weight were observed (Table 7). The F2 generation had a significant and negative correlation with the F5 generation for days to maturity, whereas F3 and F4 generation showed significant and positive correlations with the F5 for the same character. The F3, F4 and F5 generations were also found to have a significant and positive associations with the F6 generation for days to 50% flowering. Interestingly, these five generations

Table 6: Correlations among the F2 to F6 generations based on the mean yields of the entries.

	F2	F3	F4	F5	F6
F2	1.0000	0.6743*	-0.0718	0.5167	0.0357
F3		1.0000	0.0380	0.2108	0.4311
F4			1.0000	0.0946	-0.2704
F5				1.0000	-0.2297
F6					1.0000

* Significant at 5%

Table 7: Correlations among the F2 to F6 generations for different characters.

Character		F2	F3	F4	F5	F6
Days to 50% flowering	F2	1.0000	0.7025**	0.3542**	-0.0033	0.0055
	F3		1.0000	0.5513**	0.1083	0.4079**
	F4			1.0000	0.4224**	0.6977**
	F5				1.0000	0.3867**
	F6					1.0000
Days to maturity	F2	1.0000	0.6504**	0.1886	-0.2145*	0.1689
	F3		1.0000	0.5982**	0.3807**	0.2421*
	F4			1.0000	0.6635**	0.2335*
	F5				1.0000	-0.0652
	F6					1.0000
Plant height	F2	1.0000	0.0093	-0.1943	0.1304	0.1056
	F3		1.0000	-0.0427	0.1163	0.1720
	F4			1.0000	-0.0444	-0.0759
	F5				1.0000	-0.0325
	F6					1.0000
Primary branches	F2	1.0000	0.2017	-0.1645	-0.0107	0.1024
	F3		1.0000	-0.0040	-0.0353	-0.0591
	F4			1.0000	-0.0521	-0.1544
	F5				1.000	0.1282
	F6					1.0000
Secondary branches	F2	1.0000	0.0307	-0.0922	-0.0381	0.1152
	F3		1.0000	0.1792	0.0399	-0.0845
	F4			1.0000	0.0567	0.0364
	F5				1.0000	-0.1580
	F6					1.0000
Pods/plant	F2	1.0000	-0.0501	-0.0847	0.1609	0.0769
	F3		1.0000	0.1058	-0.0186	0.0368
	F4			1.0000	-0.1503	-0.0043
	F5				1.0000	0.0157
	F6					1.0000
Seeds/plant	F2	1.0000	0.1174	0.0736	0.1644	-0.0069
	F3		1.0000	0.1146	0.0245	-0.0316
	F4			1.0000	-0.1203	0.0520
	F5				1.0000	-0.0459
	F6					1.0000
20 seeds wt	F2	1.0000	0.4136**	0.3059**	-0.0924	0.0099
	F3		1.0000	0.2682**	-0.0483	-0.0095
	F4			1.0000	0.2093*	0.0226
	F5				1.0000	-0.2267*
	F6					1.0000

Table 7 (Contd.)

Character		F2	F3	F4	F5	F6
Yield/plant	F2	' 1.0000	-0.0714	-0.0248	-0.0458	0.0653
	F3		1.0000	0.3237**	-0.0047	-0.1108
	F4			1.0000	0.0477	0.0537
	F5				1.0000	-0.1529
	F6					1.0000

F2 to F6 = Generations
* Significant at 5%
** Significant at 1%

namely F2, F3, F4, F5 and F6 were not observed to have any significant relationship among themselves for the major characters such as numbers of primary and secondary branches, number of pods, number of seeds and yield per plant (Table 7). The correlation values between mean yield of F2 and F3 was significant and positive while for mean yield per plant was only positive and significant between F3 and F4 generation indicating that mean yield per plant and per plot do not influence each other.

4.1.4. Correlation among yield components in different generations

To determine the relationships between yield and yield components and among themselves in different generations, correlations were estimated in F2, F3, F4, F5 and F6 separately and presented in Table 8.

4.1.4.1. F2 generation

The correlation values estimated in F2 generation showed that yield per plant had significant negative associations with days to 50% flowering (-0.3262**) and maturity (-0.2724**). Yield per plant had significant positive correlations with plant height, numbers of primary and secondary branches, numbers of pods and seeds per plant and 20-seed weight (Table 8). Most of the characters exhibited positive relationships among themselves except 20-seed weight which had significant negative correlation with days to 50% flowering.

4.1.4.2. F3 generation

The results of this study showed that yield per plant had significant positive correlations with the numbers of primary and secondary branches, numbers of pods and seeds per plant and 20-seed weight (Table 8). It showed no significant correlation with days to 50% flowering and maturity and plant height. Twenty seed weight had significant negative correlations with days to 50% flowering and maturity and number of seeds per plant. All the characters showed non significant association with plant height. The number of primary branches had significant positive correlations with the number of secondary branches and number of pods per plant. Days to 50% flowering revealed significant positive correlations with number of pods per plant, number of seeds per plant and number of secondary branches. The highest correlation values of 0.8044** and 0.7045** were obtained between number of pods and seeds per plant and number of pods and secondary branches. The number of seeds per plant had significant positive relationships with the number of pods per plant, number of secondary branches, numbers of days to 50% flowering and maturity.

4.1.4.3. F4 generations

The seed yield per plant was found to have significant positive associations with all the major yield components except with days to 50% flowering and maturity. Days to 50% flowering and maturity showed significant correlations with the numbers of pods and seeds per plant (Table 8). All the characters had

Table 8: Analysis of relationships among yield components in F2, F3, F4, F5 and F6 generations of chickpea.

	DF	DM	Pt.Ht	P.Br	S.Br	Pods/pt	Seeds/pt	20seedwt	Yield/pt
F2 Generation									
DF	1.0000	0.8990**	-0.0899	0.1783	0.0165	0.1434	0.3136**	-0.5660**	-0.3262**
DM		1.0000	-0.1463	0.1053	0.0332	0.1333	0.3076**	0.5778**	-0.2724**
Pt.Ht			1.0000	0.2057*	0.1179	0.2278*	0.1857	0.2536*	0.4556**
P.Br				1.0000	0.1355	0.5523**	0.5077**	0.0094	0.3458**
S.Br					1.0000	0.3591**	0.3044**	0.8580**	0.4361**
Pods/pt						1.0000	0.9491**	-0.1146	0.5159**
Seeds/pt							1.0000	0.2884**	0.3894**
20 seed wt								1.0000	0.3674**
Yield/pt									1.0000
F3 Generation									
DF	1.0000	0.5800**	-0.1547	0.1066	0.2749**	0.3346**	0.3895**	-0.4350**	0.0367
DM		1.0000	-0.1262	-0.0473	0.0879	0.2068*	0.3257**	-0.4807**	-0.0284
Pt.Ht			1.0000	-0.0667	0.0170	-0.0016	0.0957	0.1926	0.2065
P.Br				1.0000	0.3244**	0.3307**	0.1928	0.0376	0.2182*
S.Br					1.0000	0.7045**	0.5650**	0.0100	0.5254**
Pods/pt						1.0000	0.8044**	-0.0931	0.6660**
Seeds/pt							1.0000	-0.3337**	0.4773**
20 seed wt								1.0000	0.4174**
Yield/pt									1.0000
F4 Generation									
DF	1.0000	0.2495**	0.1225	0.0632	0.1244	0.2186*	0.2193*	-0.1437	0.0368
DM		1.0000	0.0898	0.0449	0.0925	0.2350*	0.2785**	-0.1475	0.1297
Pt.Ht			1.0000	0.0936	0.3331**	0.3385**	0.3366**	0.0212	0.3780**
P.Br				1.0000	0.0669	0.2789**	0.2767**	0.1013	0.2876**
S.Br					1.0000	0.6579**	0.6623**	-0.0920	0.5383**
Pods/pt						1.0000	0.9557**	-0.0903	0.7382**
Seeds/pt							1.0000	-0.1612	0.7325**
20 seed wt								1.0000	0.4367**
Yield/pt									1.0000
F5 Generation									
DF	1.0000	0.7888**	-0.1275	0.1838	-0.0694	0.0586	0.0480	-0.0808	0.0292
DM		1.0000	-0.1251	0.0695	-0.0103	-0.0584	-0.0545	-0.0478	-0.0355
Pt.Ht			1.0000	-0.0130	0.2885**	0.1157	0.0934	0.1110	0.1397
P.Br				1.0000	0.1142	0.5747**	0.5484**	0.1002	0.5416**
S.Br					1.0000	0.6075**	0.5647**	0.0922	0.5707**
Pods/pt						1.0000	0.9568**	-0.0101	0.8513**
Seeds/pt							1.0000	-0.0819	0.8441**
20 seed wt								1.0000	0.4170**
Yield/pt									1.0000

Table 8 (Contd.)

	DF	DM	Pt.Ht	P.Br	S.Br	Pods/pt	Seeds/pt	20seedwt	Yield/pt
F6 Generation									
DF	1.0000	0.5916**	-0.1237	-0.0976	-0.0256	-0.0922	0.0268	-0.1201	-0.0736
DM		1.0000	-0.0442	-0.0222	0.1093	-0.1166	-0.0039	-0.302	-0.0550
Pt.Ht			1.0000	-0.1659	0.1023	-0.0258	-0.0202	0.3968**	0.1150
P.Br				1.0000	0.3185**	0.4576**	0.4466**	0.1373	0.4725**
S.Br					1.0000	0.6548**	0.6445**	0.2384*	0.7015**
Pods/pt						1.0000	0.9147**	0.0773	0.8334**
Seeds/pt							1.0000	0.0523	0.8317**
20 seed wt								1.0000	0.4887**
Yield/pt									1.0000

DF = Days to 50% flowering; DM = Days to maturity; Pt.Ht = Plant height;
P.Br = Primary branches; S.Br = Secondary branches; pt = Plant; 20 seed wt = 20 seed weight.

* Significant at 5%

** Significant at 1%

positive correlations among themselves except the 20-seed weight which had no significant relationships with any of these characters. The number of pods per plant had the strongest association (0.9557**) with the number of seeds per plant. There were also high correlations between number of pods per plant and yield per plant and number of seeds per plant and yield per plant. Number of seeds per plant had significant positive correlations with days to 50% flowering and maturity, plant height, numbers of primary branches and secondary branches and pods per plant (Table 8). Plant height showed significant positive associations with secondary branches, number of pods per plant and number of seeds per plant. Days to 50% flowering had also significant positive relationships with days to maturity.

4.1.4.4. F5 generation

In this generation days to 50% flowering had only significant positive correlation with the number of days to maturity. Days to maturity showed no significant relationship with all other characters. Similarly, plant height had only a significant positive correlation with secondary branches. The number of primary branches had significant positive associations with numbers of pods and seeds per plant and yield per plant. The significant positive relationships were observed between number of seeds per plant and numbers of primary and secondary branches. The highest correlation of 0.9568** was obtained between the number of pods and number of seeds per plant. Seed yield per plant was found to have significant positive correlations with the numbers of primary and secondary branches, numbers of pods and seeds per plant and 20-seed weight (Table 8).

4.1.4.5. F6 generation

The relationships studied in this generation showed that days to 50% flowering and maturity had no significant correlation with other characters. Plant height was significantly and positively correlated with 20-seed weight but did not show significant relation with seed yield per plant. Number of primary branches had significant correlation with number of secondary branches, number of pods and seeds per plant and yield per plant (Table 8). Number of secondary branches had also significant positive correlations with numbers of pods and seeds per plant, 20-seed weight and yield per plant. The number of pods had the highest correlation value of 0.9147** and 0.8334** with number of seeds per plant and seed yield per plant respectively. Twenty seed weight exhibited significant positive correlations with only plant height, secondary branches and yield per plant. Generally, yield per plant showed significant positive associations with numbers of primary and secondary branches, numbers of pods and seeds per plant and 20-seed weight.

4.1.5. Correlations between yield and other characters for combined data of all generations

When combined data of F2, F3, F4, F5 and F6 generations were analyzed to determine the associations among these characters, days to 50% flowering and maturity showed no significant correlations with yield per plant. On the other hand, plant height, number of primary and secondary branches, pods and seeds per plant and 20 seed weight were found to have strong

Table 9: Analysis of relationships among yield components in combined F2, F3, F4, F5 and F6 generations.

	DF	DM	Pt.Ht	P.Br	S.Br	Pods/pt	Seed/pt	20seedwt	Yield/pt
DF	1.000	0.5026**	0.0906	0.1099*	0.1310**	0.1333**	0.2297**	-0.3003**	-0.0775
DM		1.0000	-0.0592	0.0517	0.0967	0.1045*	0.2173**	-0.3387**	-0.0672
Pt.Ht			1.0000	0.0297	0.1836**	0.1310**	0.1478**	0.1576**	0.2297**
P.Br				1.0000	0.1942**	0.4597**	0.4248**	0.0579	0.3719**
S.Br					1.0000	0.5747**	0.5144**	0.0136	0.5569**
Pods/pt						1.0000	0.9135**	-0.0619	0.7182**
Seeds/pt							1.0000	-0.1935**	0.6245**
20 seed wt								1.0000	0.4121**
Yield/pt									1.0000

DF = Days to 50% flowering; DM = Days to maturity; Pt.Ht = Plant height;
P.Br = Primary branches; S.Br = Secondary branches; pt = Plant;
20 seed wt = 20 seed weight.

* Significant at 5%
** Significant at 1%

significant correlations with seed yield per plant (Table 9). All these characters except 20-seed weight were significantly and positively correlated among themselves. Twenty seed weight is negatively correlated with days to 50% flowering and maturity, pods per plant and seed yield per plant (Table 9). Days to 50% flowering also had highly significant and positive correlation with days to maturity in all the generations. The two major yield components, pods per plant and seeds per plant had positive associations with other characters such as days to maturity, plant height, primary and secondary branches (Table 9). Plant height had no association with days to flowering and maturity in all the generations (Table 8).

4.2. Experiment II

The objectives of this experiment were 1. to determine the effect of different spacings on single plant selection in F4 progenies and 2. to establish criteria for single plant selection in F4 which can help to predict the performance of the progenies in F5 generation. The observations were collected on single plant selection in 1985/86 crop season. The seeds of these selections were planted in 1986 as F5 progenies.

4.2.1. Mean yields of the progenies selected from 9 crosses at two spacings:

When the overall means and ranges of the yields of the progenies of the selected plants from different spacings of F4 generation were compared based on their yields per plot in 1986/87, there were significant differences. The over all mean yield of the progenies in a wide spacing was 2777 kg/ha as compared to 2843 kg/ha in close spacing (Table 11). Generally, the progenies of the plants selected from wide spacing gave better yield than the check (bulk F5) in most of the families (Table 10). No progeny of the plants selected from close spacing gave more yield than check (bulk F5) in the cross RSG 44 x Phule G-7 while three progenies of the selected plants from wide spacing yielded more than this check (Table 10). There were statistically significant differences between the mean yields of the two spacings, among the lines within wide spacing and spacing vs check (bulk F5) in this cross (Table 12). In the family 2375 x JG 315,twelve progenies of the plants selected from close spacing and seventeen progenies of the plants selected from wide spacing

Table 10. Mean days to 50% flowering, maturity and yield (kg/ha) of different treatments in experiment II.

Plant No.	30cm x 10cm			60cm x 20cm			Random Selection		
	DF	DM	'YIELD	DF	DM	YIELD	DF	DM	YIELD
				Family 1: 2375 x JG-315					
1	45	91	2290	49	94	2255	49	96	1780
2	46	96	2324	58	99	3236	44	86	1924
3	48	96	2293	54	93	3411	48	89	3302
4	48	97	2882	51	93	3093	45	88	4018
5	56	98	3253	56	99	3859	60	100	3760
6	42	93	3024	39	83	3198	42	96	4484
7	58	99	3660	47	91	3069	55	99	3468
8	42	91	2781	50	95	2593	42	87	3098
9	43	89	1330	46	92	3444	48	97	2624
10	44	89	1772	51	98	4460	51	92	1734
11	58	101	4170	55	96	3036	44	85	3921
12	49	93	2624	42	90	3546	42	93	2605
13	47	93	2141	57	100	2495	57	99	2635
14	44	99	2169	51	99	3255	60	100	3325
15	48	96	2563	44	92	1853	45	96	3477
16	47	92	2163	50	99	2733	49	87	2945
17	55	99	4013	47	97	2944	44	96	3153
18	44	92	2367	56	100	3582	51	98	5431
19	41	88	3450	42	88	2976	49	99	1958
20	54	100	4823	44	89	2373	41	98	3281
21	40	89	2774	47	94	2788	49	99	5022
22	48	95	2466	49	94	2981	49	96	3268
23	41	88	2131	43	85	2022	46	96	3245
24	43	85	1989	47	94	3705	58	101	3789
25	41	85	2521	46	90	2597	51	96	4938
26	48	97	3082	56	100	4171	44	96	869
27	48	93	1865	44	93	2230	44	93	1334
28	43	88	4272	44	93	2797	60	102	4116
29	46	92	2963	46	92	1676	60	100	3136
30	46	87	2981	43	89	1511	60	103	1863
Bulk	42	87	2797	42	87	2797	42	87	2797
Mean			2363			3013			3240

Standard Error of Mean for	DF	DM	YIELD
Entries	2.3	3.1	531.4
Spacings	0.4	0.6	96.9
Family	0.3	0.4	68.6
Randomly selected (mean of 30 plants)	0.6	0.8	137.3
CV%(entries)	6.9	4.7	26.4

DF - Days to 50% flowering ; DM - Days to maturity

Plant No.	30cm x 10cm DF	DM	YIELD	60cm x 20cm DF	DM	YIELD	Random Selection DF	DM	YIELD
' Family 2: 64-3 x BDN9-3									
1	40	87	2768	50	96	3202	53	96	1722
2	41	83	2070	53	97	4076	49	96	2875
3	44	89	2353	37	81	1652	45	93	4598
4	44	89	3215	44	90	2120	45	98	3849
5	45	91	2068	48	93	2436	49	94	3151
6	40	82	2476	47	94	3864	58	97	3323
7	46	93	2144	38	83	2008	58	100	4254
8	46	91	2859	44	90	3120	40	80	2673
9	45	90	2442	40	88	2544	49	94	4022
10	44	85	2608	40	88	2365	47	83	2121
11	43	93	2978	47	90	2574	34	82	2394
12	41	88	1800	48	95	3702	49	90	3828
13	54	96	2254	39	84	3700	49	86	1051
14	49	91	2341	46	97	2821	45	96	3394
15	47	92	2939	55	91	3509	46	96	3880
16	47	90	2420	43	86	3172	46	96	4217
17	55	99	3622	44	88	2995	58	99	3867
18	46	88	1916	48	94	3634	47	92	1624
19	51	95	1979	51	97	3809	46	92	3268
20	46	91	2222	49	92	2500	49	91	4144
21	48	95	3588	43	90	2029	50	96	1578
22	49	94	2015	56	99	3094	41	81	2133
23	55	97	1403	60	98	3175	45	90	1380
24	44	93	3575	42	86	3092	50	97	3642
25	43	90	2919	52	91	3102	35	95	1063
26	45	89	2709	44	85	3020	51	97	2935
27	36	86	2470	41	91	2291	53	96	2025
28	46	87	2623	42	86	2451	56	96	3298
29	43	89	3061	44	87	2414	48	95	3203
30	40	86	2871	38	81	1651	45	90	687
Bulk	48	91	3203	48	91	3203	48	91	3203
Mean			2663			2880			2883

Standard Error of Mean for	DF	DM	YIELD
Entries	2.0	3.5	481.5
Spacings	0.4	0.6	87.9
Family	0.3	0.5	62.1
Randomly selected (mean of 30 plants)	0.5	0.9	124.4
CV%(entries)	6.2	5.4	25.0

Plant No.	30cm x 10cm			60cm x 20cm			Random Selection		
	DF	DM	YIELD	DF	DM	YIELD	DF	DM	YIELD
			Family 3: Phule G-12 x 2E						
1	47	88	1912	49	93	4761	55	97	2757
2	45	89	1508	39	81	2007	49	85	3233
3	39	85	2406	41	85	2205	50	92	3026
4	44	88	1976	45	88	3301	41	85	1805
5	43	84	1973	41	87	2210	42	85	2024
6	46	98	3456	53	99	2241	48	90	2520
7	43	88	2837	44	85	2575	49	96	2332
8	44	88	3520	42	87	3283	58	100	4105
9	46	89	2063	39	85	3107	49	90	1498
10	44	90	2214	44	89	2680	43	90	2211
11	47	89	2624	49	97	3549	48	92	2368
12	49	95	2770	43	88	1835	40	86	2964
13	42	83	3345	46	92	2813	49	90	2020
14	46	90	3050	42	88	3173	49	91	2305
15	54	98	3693	39	83	3443	48	96	3296
16	46	90	1964	46	88	3236	35	84	1656
17	53	95	3541	45	91	2641	38	86	2320
18	53	94	3894	50	93	3752	47	89	1924
19	44	87	2856	49	95	2762	45	97	3802
20	51	97	2531	41	83	2885	45	90	2828
21	47	90	1373	50	94	3927	38	82	2043
22	42	82	1816	51	96	2473	37	80	1824
23	42	98	2360	49	90	2924	42	88	2949
24	40	90	3012	41	92	2828	60	98	1753
25	40	87	1803	49	93	3355	49	95	1805
26	45	95	3318	49	95	4698	50	97	3280
27	42	90	3575	45	95	3175	40	90	4110
28	43	88	1719	47	93	2738	45	88	1904
29	45	87	2892	50	95	2486	42	90	2426
30	42	89	4087	49	94	2701	50	94	1296
Bulk	46	90	2154	46	90	2154	46	90	2154
Mean			2653			2966			2470

Standard Error of Mean for	DF	DM	YIELD
Entries	2.2	2.2	494.5
Spacings	0.4	0.4	90.2
Family	0.3	0.3	63.8
Randomly selected (mean of 30 plants)	0.6	0.6	127.7
CV%(entries)	6.9	3.5	24.8

Plant No.	30cm x 10cm DF	DM	YIELD	60cm x 20cm DF	DM	YIELD	Random Selection DF	DM	YIELD
				Family 4: Phule G-12x64-3					
1	50	95	2942	52	94	2539	51	99	4203
2	41	84	2856	49	95	4258	54	91	1777
3	42	87	1886	45	90	2961	48	90	3928
4	40	84	2258	49	90	1752	56	99	3225
5	40	83	3135	54	101	3250	49	86	2540
6	46	88	2213	49	90	2742	58	99	3733
7	47	86	2079	48	89	2529	45	89	2876
8	43	89	1871	50	94	3045	50	96	3322
9	51	93	2687	57	99	2723	58	99	4330
10	52	97	2978	45	90	3198	51	97	3840
11	48	93	2921	45	88	3621	55	99	3758
12	51	96	1839	53	92	2517	58	100	1697
13	54	100	4409	51	89	2356	45	88	3139
14	47	95	2297	47	87	2748	54	96	2173
15	38	83	2253	46	86	2641	49	88	3468
16	47	87	3322	56	102	4281	44	88	3176
17	47	90	2027	55	99	3870	46	85	2132
18	49	90	2996	51	89	1652	47	93	2587
19	55	98	2330	45	91	2694	45	82	2218
20	52	94	2425	51	91	2692	51	97	4540
21	49	94	3498	56	98	2754	60	99	2545
22	42	86	2881	49	90	2422	46	98	3531
23	53	98	3983	47	94	3496	45	90	2368
24	40	83	2120	42	89	2837	55	97	3484
25	44	87	2147	42	88	2576	44	90	4024
26	55	96	2361	50	90	2781	49	90	3173
27	48	91	2158	50	90	2873	60	99	2829
28	39	87	2255	50	91	2379	47	92	2016
29	42	86	2620	50	93	2760	50	97	2386
30	41	84	1667	48	96	3590	45	90	3451
Bulk	47	96	3444	47	96	3444	47	96	3444
Mean			2610			2903			3093

Standard Error of Mean for	DF	DM	YIELD
Entries	2.5	2.2	359.5
Spacings	0.5	0.4	65.6
Family	0.3	0.3	46.4
Randomly selected (mean of 30 plants)	0.6	0.6	92.9
CV%(entries)	7.3	3.4	18.5

Plant No.	30cm x 10cm DF	DM	YIELD	60cm x 20cm DF	DM	YIELD	Random Selection DF	DM	YIELD
				Family 5: RSG-44 x Phule G-7					
1	42	83	3178	53	91	3229	37	85	3164
2	43	87	2672	53	94	2825	58	98	982
3	37	82	1718	49	92	2635	50	98	3224
4	38	85	2664	48	88	1927	37	84	3238
5	44	88	2748	44	87	2887	42	87	2891
6	55	98	3010	54	98	1880	58	99	2829
7	46	84	2077	44	85	2661	38	84	1917
8	37	78	2031	47	89	3701	50	99	4457
9	41	88	3648	52	95	2865	55	93	1544
10	39	78	2064	37	82	3229	38	84	2592
11	41	90	3762	39	86	2643	40	90	4863
12	42	83	1714	48	90	1744	37	78	2500
13	38	84	3568	47	91	4052	46	83	2284
14	37	83	2344	39	88	3890	51	92	3974
15	42	90	3065	48	91	4915	47	86	2620
16	51	95	2780	43	88	2757	51	99	2572
17	50	93	2473	42	82	3112	55	100	4431
18	41	85	2102	45	86	2455	46	92	2866
19	46	89	1867	52	97	2554	43	88	2998
20	45	83	1444	40	80	2050	37	80	2382
21	50	93	3650	42	83	3189	47	90	4302
22	47	89	2547	42	86	3536	43	85	2765
23	52	94	2935	45	92	2982	51	94	4333
24	45	89	2160	39	83	2670	46	90	1585
25	54	96	3725	55	98	2899	43	88	2736
26	36	77	1785	46	90	3089	40	84	1900
27	39	81	2370	39	79	1661	54	96	4004
28	40	83	3068	55	99	2661	41	84	2713
29	40	83	2132	38	83	2557	38	85	4756
30	44	90	2145	40	81	3279	53	99	3220
Bulk	47	96	3789	47	96	3789	47	96	3789
Mean			2620			2936			2997

Standard Error of Mean for	DF	DM	YIELD
Entries	2.1	1.0	522.0
Spacings	0.4	0.2	95.3
Family	0.3	0.1	67.4
Randomly selected (mean of 30 plants)	0.5	0.3	134.9
CV%(entries)	6.6	2.8	26.8

Plant No.	30cm x 10cm DF	DM	YIELD	60cm x 20cm DF	DM	YIELD	Random Selection DF	DM	YIELD
			Family 6: JG1265 x Phule G-7						
1	46	95	3463	46	94	2363	53	97	3835
2	49	88	2469	58	100	2399	50	103	4032
3	47	91	1955	44	98	3212	43	88	3415
4	43	85	1728	38	78	2958	42	85	3842
5	48	93	3603	48	98	2772	52	96	4073
6	42	92	2788	57	97	3912	56	102	3177
7	46	95	1476	48	97	2950	46	93	3944
8	45	85	3497	55	97	4029	55	96	2647
9	42	89	2207	52	98	3615	40	90	2658
10	45	95	2551	49	99	2615	55	100	2841
11	47	91	3089	46	90	3412	55	98	2549
12	43	87	2735	37	84	2410	47	100	2099
13	37	79	2395	41	92	2986	56	96	3649
14	41	93	3193	55	99	4120	42	85	1431
15	47	97	3811	52	98	3813	55	92	2373
16	43	84	1637	44	85	1510	40	98	3796
17	55	98	2871	54	98	3290	38	83	2908
18	44	89	2250	46	96	2043	53	96	2273
19	47	88	3490	40	92	2461	53	97	3196
20	47	97	2433	47	85	2663	40	81	1664
21	46	91	2975	41	90	3350	40	85	2295
22	48	96	3867	38	79	2667	50	97	1793
23	47	85	2196	48	90	2600	42	85	2723
24	47	95	2132	39	84	3089	46	98	1987
25	45	97	1416	41	85	3435	55	97	3009
26	47	90	2965	40	83	2802	46	85	2013
27	49	95	3388	55	100	3106	56	104	3005
28	43	90	2343	39	87	2624	45	85	1642
29	52	96	2494	39	79	2565	46	90	2176
30	48	87	1792	40	83	2459	45	83	1587
Bulk	47	94	2705	47	94	2705	47	94	2705
Mean			2663			2933			2753

Standard Error of Mean for	DF	DM	YIELD
Entries	2.3	3.5	529.1
Spacings	0.4	0.6	96.5
Family	0.3	0.5	68.3
Randomly selected (mean of 30 plants)	0.6	0.9	136.7
CV%(entries)	7.2	5.4	26.8

Plant No.	30cm x 10cm			60cm x 20cm			Random Selection		
	DF	DM	YIELD	DF	DM	YIELD	DF	DM	YIELD
			Family 7: JG1265 x 2375						
1	47	93	2758	53	98	4327	38	81	2107
2	57	95	1273	42	88	3542	46	92	2610
3	47	91	2808	45	85	3237	38	80	2187
4	42	91	2639	40	90	3565	46	90	3986
5	43	87	3028	45	90	3314	46	90	1226
6	44	90	3269	43	89	4088	52	92	2720
7	46	92	1452	41	89	4314	55	96	4063
8	45	88	3632	50	96	3965	46	97	2996
9	43	88	3213	45	90	2771	42	90	2036
10	42	92	3009	40	87	2602	51	99	2731
11	50	93	3278	41	91	3286	47	88	3204
12	44	85	3097	44	87	2432	51	92	2493
13	43	85	2896	44	92	4022	49	99	4246
14	38	92	3991	43	94	2968	43	85	2660
15	43	90	2065	45	89	2599	56	100	3596
16	44	90	2085	43	89	2742	47	90	2574
17	50	96	3257	48	92	3653	56	99	2505
18	43	87	3028	48	93	2165	44	88	2814
19	55	97	2379	39	81	2234	40	88	2664
20	50	95	2332	44	90	3080	44	85	2267
21	46	92	2837	47	92	1871	43	86	2367
22	50	88	1671	46	92	4064	51	98	2682
23	52	92	1838	45	89	2706	60	102	3616
24	48	88	3330	44	89	4048	45	84	3474
25	47	91	2360	42	88	3838	41	97	4506
26	49	90	2500	43	89	3493	39	90	4138
27	44	89	1647	45	87	2854	51	91	2782
28	44	89	3317	45	85	2551	52	96	1448
29	54	97	2997	43	88	3461	38	87	4160
30	54	97	3214	41	85	1277	53	94	2372
31	42	93	3418	42	93	3418	42	93	3418
Mean			2697			3177			2923

Standard Error of Mean for	DF	DM	YIELD
Entries	2.8	1.0	525.3
Spacings	0.5	0.2	95.9
Family	0.4	0.1	67.8
Randomly selected (mean of 30 plants)	0.7	0.3	135.7
CV%(entries)	8.8	3.2	25.2

Plant No.	30cm x 10cm DF	DM	YIELD	60cm x 20cm DF	DM	YIELD	Random Selection DF	DM	YIELD
				Family 8: ICCC-6 x 2375					
1	43	94	2283	58	99	2874	46	98	2886
2	45	97	3298	46	91	2912	42	90	2118
3	44	86	2263	48	98	1923	44	85	3560
4	43	87	2441	42	87	3776	47	98	2074
5	43	91	2850	47	98	3617	40	86	3487
6	52	94	2699	48	99	3602	45	90	1369
7	42	86	2469	53	96	3997	49	90	2791
8	45	94	3251	40	82	2603	51	93	1698
9	52	96	3330	54	96	3736	44	88	2808
10	42	86	2517	49	98	2843	40	82	3449
11	39	87	2541	46	95	3010	46	100	3485
12	41	87	3113	51	99	3938	42	88	2147
13	47	94	2470	45	96	3484	42	90	2117
14	45	93	2105	42	86	2643	56	99	1627
15	47	97	3276	42	90	3652	42	88	2751
16	41	86	2121	43	86	2977	42	82	2040
17	47	91	3703	57	100	3662	48	99	4827
18	48	89	2501	48	96	2994	51	96	3462
19	45	93	2818	43	86	2253	47	98	2235
20	49	92	2497	40	83	2636	42	88	2652
21	56	97	2085	45	88	2242	48	88	2551
22	46	94	2958	41	93	2195	35	82	1844
23	47	89	2809	43	85	2274	48	95	3686
24	42	87	2406	41	85	2063	51	88	987
25	47	94	2484	47	88	2964	56	96	3541
26	53	101	3369	42	85	2309	47	98	3326
27	44	91	3098	49	95	3078	49	96	2926
28	48	95	3573	44	92	3072	47	97	3722
29	52	98	3643	47	92	2215	61	102	2246
30	47	90	1656	45	92	3287	49	98	3410
Bulk	46	96	2411	46	96	2411	46	96	2411
MEAN			2710			2943			2717

Standard Error of Mean for	DF	DM	YIELD
Entries	2.0	3.1	537.2
Spacings	0.4	0.6	98.0
Family	0.3	0.4	69.3
Randomly selected (mean of 30 plants)	0.5	0.8	138.7
CV%(Entries)	6.0	4.8	26.7

Plant No.	30cm x 10cm DF	DM	YIELD	60cm x 20cm DF	DM	YIELD	Random Selection DF	DM	YIELD
				Family 9: ICCC-6 x JG-315					
1	44	88	3392	42	91	3254	41	92	3682
2	44	89	2615	46	90	2137	52	91	3273
3	42	89	4047	42	83	1999	50	90	1259
4	44	91	2320	43	88	3404	37	90	4691
5	50	94	3533	40	83	2900	44	86	3079
6	42	85	2759	41	85	3901	60	99	4204
7	45	89	1797	50	97	3732	49	90	2350
8	45	85	2667	47	91	1891	40	88	2167
9	47	91	2140	45	88	2079	50	91	3798
10	44	90	3765	48	90	2585	47	91	1926
11	54	99	2951	50	95	3574	42	88	1832
12	49	93	3017	48	94	3494	48	93	1093
13	46	90	2274	42	86	2361	57	97	3047
14	50	94	2812	47	90	3386	55	96	3191
15	43	87	3582	55	99	4031	41	89	4578
16	57	99	3229	47	88	2228	50	90	3534
17	49	100	2870	47	94	2509	50	98	3899
18	40	85	3063	47	94	2606	45	90	3126
19	47	88	3046	50	93	1261	52	85	1182
20	48	94	2046	46	92	3060	45	89	2825
21	47	94	2347	46	97	4219	56	98	3024
22	58	98	2109	47	93	3290	38	87	3357
23	46	91	1965	57	100	3361	44	98	2229
24	48	95	2754	42	88	4365	50	97	4651
25	46	92	2301	43	90	2324	46	90	2531
26	50	94	2099	42	87	2920	50	94	1951
27	50	90	2250	43	90	2627	46	90	1980
28	51	95	3618	41	86	2990	48	89	2488
29	44	87	2543	45	91	2772	42	85	3109
30	41	85	2482	44	93	2252	40	92	3249
Bulk	45	89	2370	45	89	2370	45	89	2370
Mean			2733			2900			2893

Standard Error of Mean for	DF	DM	YIELD
Entries	2.1	2.7	517.4
Spacings	0.4	0.5	94.4
Family	0.3	0.4	66.8
Randomly selected (mean of 30 plants)	0.5	0.7	133.6
CV%(entries)	6.4	4.3	25.9

gave more yield than the check (bulk F5), but none of them had significantly higher yield than the check (Table 12). Spacing vs check (F5 bulk) was found to be non significant in all the families except in the family RSG44 x Phule G-7. The wide spacing had higher mean yield (mean of 30 progenies per spacing) than close spacing in all the families (Table 10). Selection from close spacing did not show an advantage over random selection whereas selection from wide spacing gave an advantage of 20%, 7%, 9% and 8% in the families of Phule G-12 x 2E, JG 1265 x Phule G-7, JG 1265 x 2375 and ICCC 6 x 2375 respectively. Of these the 20% advantage was significantly different from the mean yield of randomly selected plants. Selection from wide spacing gave advantage of 9% (family 8 and 9) to 28% (family 1) over selection from close spacing. The efficiency of selection was about the same as that of random selection in the families 64-3 x BDN9-3 and ICCC 6 x JG 315.

4.2.2. Yield components of the single plant selections

4.2.2.1. Days to 50% flowering and maturity

Days to 50% flowering and maturity were in the range of 42 to 52 and 95 to 106 days respectively for all the plants selected from the F4 generation in 1985/86 (Table 11). These days to 50% flowering and maturity were the average of the segregating populations on a plot basis. But when the single plant selections were sown in the F5 progeny rows in 1986/87, their days to 50% flowering and maturity ranged from 34 to 60 and 77 to 104 days (Table 10). The lines which were early to flower and mature gave relatively low yields as compared to those which were of the late maturity group. However, this statement is not true for all the selections since there were some exceptions. The late lines had relatively more pods and seeds per plant in the F4.

4.2.2.2. Number of pods and seeds per plant

When selection was made in 1985/86, the plants with the highest number of pods per plant had also the highest number of seeds per plant. The number of pods per plant was significantly correlated with the number of seeds per plant. Among the selections, plant No.2 of the family 1 selected from wide spacing, plant No.1 and No. 25 of the family 2 selected from wide spacing and plant No.12 and No.16 of the family 8 selected from wide spacing had 200, 274, 203, 217 and 220 pods per plant and 203, 290, 202, 252 and 250 seeds per plant in F4. The yields of the progenies of these lines in F5 were 3236 kg/ha 3202 kg/ha, 3102 kg/ha, 3938 kg/ha and 2977 kg/ha which were relatively low as compared to the yield of the other progenies which had low number of pods and seeds in F4.

4.2.2.3. Number of primary and secondary branches

The highest number of secondary branches were 40, 34 and 31 per plant in F4. These were recorded on plants No.17 and No.21 of the family 8 selected from wide spacing and plant No.3 of the family 1 that was randomly selected. The yields of the progenies of these lines in F5 were 3662 kg/ha, 2242 kg/ha and 3302 kg/ha. Similarly the highest number of primary branches recorded in F4

Table 11: The means and ranges of yield components of F4 generation in close (30 cm x 10 cm) and wide (60 cm x 20 cm) spacings.

Character	Wide spacing		Close spacing	
	Range	Mean	Range	Mean
1. Days to 50% flowering	42 - 50	46	42 - 52	44
2. Days to maturity	95 -106	101	95 -105	99
3. Plant height	26 - 54	36	23 - 48	32
4. Primary branches	2 - 20	7	2 - 15	5
5. Secondary branches	4 - 40	13	0 - 19	6
6. Pods/plant	65 -274	122	24 - 99	42
7. Seeds/plant	91 -290	137	29 -109	46
8. 20 seed weight	2.7 - 8.0	4.4	2.3 - 7.6	4.4
9. Yield/plant	15 - 56	29	5 - 22	10
10. Yield/plot (1986/87)	1260 - 4915	2777	1273 - 4822	2843

Character 1-9 = Data collected on single plant selection in 1985/86
Character 10 = Mean yield of the progenies of single plants sown in 1986/87

was 20 per plant. This was obtained from plant No.23 of the family 2 selected from wide spacing. The yield of its progeny was 3175 kg/ha. This indicates that these characters can not be used as selection criteria since the highest number of primary and secondary branches in the F4 were not accompanied by the high yield per plot in the F5 progeny.

4.2.2.4. Yield per plant

The highest yield per plant obtained in the F4 was 57.1 gm per plant. This was followed by yield of 49.4 gm, 49.3 gm, and 49.3 gm per plant. The progenies of these selections yielded 3928 kg/ha, 2876 kg/ha, 2950 kg/ha and 2874 kg/ha in the F5 generation. These yields were also low as compared to the yield of 5431 kg/ha, 5022 kg/ha, 4938 kg/ha, 4915 kg/ha, obtained from plant Nos.18, 21 and 25 of the family 1 that were randomly selected and plant No.15 of the family 5 selected from wide spacing. Therefore, the highest seed yield per plant in F4 was not necessarily accompanied by the high seed yield in F5 generation.

4.2.2.5. Seed weight

Most of the high yielding progenies were from those plants which had the highest 20-seed weight. For instance, the highest seed yield of 5431 kg/ha was obtained in F5 from a progeny of the plant which had a 20-seed weight of 6.3 gram in F4 as compared to the lowest seed weight of 2.3 gram per 20 seeds. The second highest yield of 5022 kg/ha was also obtained in F5 from a progeny of the plant which had a 20-seed weight of 6.1 gram.

Generally, most of the progenies which gave relatively high yield were from those plants which had relatively high 20-seed weight.

4.2.3. Analysis of variance for yield and other characters:

The analysis of variance revealed that there were significant differences between the mean days to 50% flowering (p=0.01) and maturity (p=0.05) of different families. There were no significant differences among the mean yields of the families (Table 12). Significant differences were obtained between the progenies within the family for days to maturity and grain yield (p=0.01), while it was non-significant for days to 50% flowering. The analysis of variance indicated that there were significant differences between the spacings for days to 50% flowering (p=0.05) and grain yield (p=0.01). The interaction between the family and spacing was statistically significant for days to 50% flowering and maturity while it was not significant for grain yield (Table 12). There were also significant differences between the mean yields of the spacings within the families of 64-3 x BDN 9-3, Phule G-12 x 64-3, Phule G-12 x 2E, RSG 44 x Phule G-7, JG 1265 x Phule G-7 and JG 1265 x 2375. When the progenies within close spacing of each family were compared, there were no significant differences between their mean yields in most of the families while there were significant differences between the mean yields of the progenies of the plants selected from wide spacings. The significant differences between the mean yields of the progenies of the plants selected from close spacing were obtained in the families of 2375 x JG 315, Phule G-12 x 2E, Phule G-12 x 64-3 and JG 1265 x Phule G-7. Except in the family of JG

Table 12: Analysis of variance in F5 for days to 50% flowering, maturity and yield for different entries in Experiment II.

Source of variation	d.f.	Mean square		
		DF	DM	Yield
Replication	1	48.18**	12.68	5727*
Family	8	139.83**	292.75*	1296
Error(family)	8	1.24	18.48	784
Within family	540	43.76	45.42**	1873**
spacing	1	57.41*	24.30	43633**
spacing x family	8	87.92**	36.27*	530
remainder	531	43.07**	45.59**	1814.19**
Error(pooled)	540	10.21	15.04	1023
<u>Within Individual family</u>				
Family 1: 2375 x JG315:				
Between spacings	1	106.41**	8.01	1526
Entries within close spacing	29	50.71**	40.67**	2624**
Entries within wide spacing	29	52.61**	41.04**	1996*
Spacing vs check	1	55.78**	74.61	11
Error(family 1)	60	10.47	19.03	1144
Family 2: 64-3 x BDN9-3				
Between spacings	1	3.333	0.07	5982.8*
Entries within close spacing	29	38.848**	31.98	1196.5
Entries within wide spacing	29	65.170**	51.53**	1777.0*
Spacing vs check	1	13.642	0.36	952.4
Error(family 2)	60	7.923	23.83	938.9
Family 3: Phule G-12 x 2E				
Between spacings	1	5.633	4.408	6324.0*
Entries within close spacing	29	29.265**	39.055**	2367.3**
Entries within wide spacing	29	32.672**	42.844**	1920.7*
Spacing vs check	1	1.593	0.000	1822.5
Error(family 3)	60	9.815	9.892	990.5
Family 4: Phule G-12 x 64-3				
Between spacings	1	255.21**	130.208**	5611.8**
Entries within close spacing	29	53.44**	53.117**	1667.3**
Entries within wide spacing	29	31.43**	35.293**	1501.7**
Spacing vs check	1	2.87	40.876*	2014.1
Error(family 4)	60	12.21	9.810	523.5
Family 5: RSG 44 x Phule G-7				
Between spacings	1	130.208**	93.633**	5577*
Entries within close spacing	29	57.218**	60.184**	1794
Entries within wide spacing	29	62.129**	63.403**	1995*
Spacing vs check	1	10.331	131.202**	4439*
Error(family 5)	60	8.592	6.090	1104

Table 12 (contd.)

Source of variation	d.f.	Mean square		
		DF	DM	Yield
Family 6: JG1265 x Phule G-7				
Between spacings	1	1.01	0.07	5498*
Entries within close spacing	29	22.65**	45.59*	1987*
Entries within wide spacing	29	85.68**	102.39**	1467*
Spacing vs check	1	3.72	19.21	29
Error(family 6)	60	10.74	24.12	1134
Family 7: JG1265 x 2375				
Between spacings	1	213.33**	73.633**	12981**
Entries within close spacing	29	42.28**	22.672**	1832
Entries within wide spacing	29	17.18	22.371**	2383**
Spacing vs check	1	20.78	17.314	920
Error(family 7)	60	15.79	8.199	1117
Family 8: ICCC 6 x 2375				
Between spacings	1	1.200	0.41	2599
Entries within close spacing	29	31.577**	35.09*	1092
Entries within wide spacing	29	43.411**	62.69**	1510
Spacing vs check	1	0.035	29.29	796
Error(family 8)	60	7.674	19.41	1169
Family 9: ICCC 6 x JG 315				
Between spacings	1	44.408*	4.03	1770
Entries within close spacing	29	36.437**	36.37**	1414
Entries within wide spacing	29	31.956**	37.50**	2286**
Spacing vs check	1	5.519	6.98	850
Error(family 9)	60	8.699	14.96	1085

d.f. = Degree of freedom
DF = Days to 50% flowering
DM = Days to maturity
* Significant at 5%
** Significant at 1%

1265 x 2375, there were significant differences between the progenies for days to 50% flowering in both close and wide spacings. Spacing vs check (bulk F5) was found to be significant for grain yield in a cross RSG 44 x Phule G-7. Similarly, it was also found to be significant for days to 50% flowering in the cross 2375 x JG 315 and for days to maturity in the cross Phule G-12 x 64-3 (Table 12). Generally, there were significant differences among the mean yields of the progenies selected from wide spacings in all the families except in the cross ICCC 6 x 2375. There were highly significant differences for days to 50% flowering and maturity among the lines selected from wide spacing in all the families but not in the cross JG 1265 x 2375 which had no significant differences for days to 50% flowering (Table 12).

4.2.4. Correlation coefficients between yield and yield components

4.2.4.1. Correlation coefficients for combined data of two spacings

The correlation studies between yield components of F4 and yield per plot of F5 and among the components from combined data of two spacings exhibited that yield per plant is strongly associated with days to 50% flowering (r=0.1986**), days to maturity (r=0.3847**), plant height (r=0.5625**), primary branches (r=0.1986**), secondary branches (r=0.5584**), pods per plant (r=0.8779**), seeds per plant (r=0.8664**) and 20-seed weight (r=0.3021**). Of these characters, number of pods per plant, number of seeds per plant and number of secondary branches were found to be the most important components. Among all the characters studied only 20-seed weight showed a significant

Table 13: Analysis of relationships between yield components of F4 and yield per plot of F5 for combined data of two spacings (30 cm x 10 cm and 60 cm x 20 cm).

	DF	DM	Pt.Ht	P.Br	S.Br	Pods/pt	Seeds/pt	20seedwt	Yield/pt	Yield/pl
DF	1.0000	0.5553**	0.1435**	0.0675	0.1841**	0.2154**	0.2354**	-0.0678	0.1986**	-0.0018
DM		1.0000	0.2193**	-0.0356	0.1603**	0.3942**	0.3932**	-0.0024	0.3847**	0.0163
Pt.Ht			1.0000	0.1668**	0.3822**	0.4816**	0.4290**	0.3473**	0.5625**	0.0334
P.Br				1.0000	0.6238**	0.2482**	0.2361**	-0.0409	0.1986**	0.0155
S.Br					1.0000	0.6193**	0.5823**	-0.0044	0.5584**	0.0161
Pods/pt						1.0000	0.9657**	-0.0695	0.8779**	-0.0531
Seeds/pt							1.0000	-0.1381**	0.8664**	-0.0649
20 seed wt								1.0000	0.3021**	0.0918**
Yield/pt									1.0000	-0.0289
Yield/pl										1.0000

DF = Days to 50% flowering, DM = Days to maturity, Pt.Ht = Plant height; P.Br = Primary branches, S.Br = Secondary branches; pt = Plant, 20seedwt = 20 seed weight; pl = plot.

* Significant at 5%

** Significant at 1%

correlation with the yield per plot (Table 13). Number of pods per plant and number of seeds per plant revealed no significant association with grain yield per plot (Table 13).Plant height had significant and positive correlations with all the characters except yield per plot (Table 13). Number of seeds per plant had significant negative correlations with seed weight. Number of seeds per plant and number of pods per plant had also significant and positive correlation with days to 50% flowering, days to maturity, plant height, primary and secondary branches (Table 13).

4.2.4.2. <u>Correlation coefficients between yield and yield components in close spacing</u>

To study the relationships between yield per plot and yield components in the close spacing (30 cm x 10 cm), the yield obtained in F5 progeny test in 1986/87 and the observations collected on days to 50% flowering and maturity, plant height, numbers of primary and secondary branches per plant, numbers of pods and seeds per plant, 20-seed weight and yield on single plant selection in 1985/86 were used.

The results showed that the number of days to 50% flowering had significant positive correlation with the number of days to maturity. These two characters did not show significant associations with other characters (Table 14). Plant height had highly significant positive correlations with the numbers of primary and secondary branches per plant, numbers of pods and seeds per plant, seed weight and yield per plant. The number of primary branches had significant positive correlation with number

Table 14: Analysis of relationships between yield components of F4 and yield per plot of F5 in close spacing (30 cm x 10 cm).

	DF	DM	Pt.Ht	P.Br	S.Br	Pods/pt	Seeds/pt	20Seedwt	Yield/pt	Yield/p
DF	1.0000	0.5368**	0.0438	0.0063	0.0162	-0.0443	0.0434	-0.0753	-0.0425	-0.0362
DM		1.0000	-0.1077	-0.0365	-0.0744	-0.0366	0.0142	-0.1117	-0.1043	-0.0247
Pt.Ht			1.0000	0.1848**	0.3008**	0.2735**	0.1984**	0.3769**	0.4906**	0.0231
P.Br				1.0000	0.4570**	0.0409	0.0329	0.0635	0.0694	0.0059
S.Br					1.0000	0.3557**	0.3173**	0.0664	0.3187**	0.0573
Pods/pt						1.0000	0.9052**	-0.1811**	0.6369**	-0.0262
Seeds/pt							1.0000	-0.3377**	0.5701**	-0.0338
20 seed wt								1.0000	0.5411**	0.1053
Yield/pt									1.0000	0.0471
Yield/pl										1.0000

DF = Days to 50% flowering; DM = Days to maturity; Pt.Ht = Plant height;
P.Br = Primary branches; S.Br = Secondary branches; pt = Plant; 20seedwt = 20 seed weight;
pl = plot.

* Significant at 5%
** Significant at 1%

of secondary branches per plant. The number of secondary branches showed significant positive associations with the numbers of pods and seeds per plant and yield per plant (Table 14). The number of pods per plant had the highest correlation value of 0.9052** with the number of seeds per plant. The numbers of pods and seeds per plant showed significant negative relationships with the seed weight. These characters showed highly significant positive associations with yield per plant (Table 14). The 20-seed weight had significant positive correlation with yield per plant. Yield per plot had no significant associations with all the characters studied.

4.2.4.3. Correlation coefficients between yield and yield components in wide spacing

The relationships between yield per plot and yield components and among each other in a wide spacing (60 cm x 20 cm) were studied. The results showed that number of days to 50% flowering had significant positive association with number of days to maturity. The number of days to maturity had also significant positive association with plant height. This character showed significant negative associations with the numbers of primary and secondary branches per plant (Table 15). Plant height had significant positive correlations with the number of pods per plant, 20-seed weight and yield per plant. The number of primary branches had significant positive association with the number of secondary branches. It had significant negative correlation with 20-seed weight. The number of secondary branches had significant positive associations with

Table 15: Analysis of relationships between yield components of F4 and yield per plot of F5 in wide spacing (60 cm x 20 cm).

	DF	DM	Pt.Ht	P.Br	S.Br	Pods/pt	Seeds/pt	20Seedwt	Yield/pt	Yield/pl
DF	1.0000	0.5068**	0.0590	0.0108	0.0921	0.0661	0.0915	-0.0746	0.0207	0.0559
DM		1.0000	0.1816**	-0.2520**	-0.1505**	0.0878	0.0558	0.0710	0.0920	0.1025
Pt.Ht			1.0000	-0.0292	0.1099	0.2674**	0.1037	0.3713**	0.4507**	0.1019
P.Br				1.0000	0.6769**	0.0561	0.0173	-0.1440*	-0.0830	0.0489
S.Br					1.0000	0.2599**	0.1381*	-0.0759	0.0893	0.0576
Pods/pt						1.0000	0.8482**	-0.1995**	0.5026**	-0.0223
Seeds/pt							1.0000	-0.3633**	0.4382**	-0.0575
20 seed wt								1.0000	0.6249**	0.0801
Yield/pt									1.0000	0.0208
Yield/pl										1.0000

DF = Days to 50% flowering; DM = Days to maturity; Pt.Ht = Plant height;

P.Br = Primary branches; S.Br = Secondary branches; pt = Plant; 20seedwt = 20 seed weight.

pl = plot.

* Significant at 5%

** Significant at 1%

the numbers of pods and seeds per plant. The number of pods per plant had highly significant positive correlation with the number of seeds per plant. These characters had significant negative associations with 20-seed weight (Table 15). Twenty seed weight had the highest significant positive correlation (0.6249**) with yield per plant in the wide spacing. Yield per plot showed no significant association with all the characters studied.

4.2.5. Path coefficient analysis

The path coefficient analysis was carried out to determine the direct and indirect effects of the yield components on yield per plot. This was only done for combined data of two spacings (30 cm x 10 cm and 60 cm x 20 cm) since there was a significant correlation between 20-seed weight and yield per plot. The results showed that the direct contribution of days to maturity, plant height, secondary branches, pods per plant and seeds per plant to yield per plot were very low (Table 16). The highest direct contribution to yield per plot was from 20-seed weight. The 20-seed weight had an indirect negative effects on yield per plot via days to maturity, secondary branches, pods per plant, seeds per plant and yield per plant (Table 16). Thus 20-seed weight did not show significant relationship with yield per plot when the data of the two spacings were separately analyzed (Tables 14 and 15).

Table 16: Path analysis of yield per plot versus days to 50% flowering and maturity, plant height, primary and secondary branches, pods, seeds, 20-seed weight and yield/plant for combined spacings (30 cm x 10 cm and 60 cm x 20 cm).

Pathways	Direct effect	Indirect effect	Correlation coefficient
1. Days to 50% flowering:	-0.0192		-0.0018
Indirect effect via:			
Days to maturity		0.0362	
Plant height		0.0046	
Primary branches		-0.0002	
Secondary branches		0.0154	
Pods/plant		0.0003	
Seeds/plant		0.0047	
20 seed weight		-0.0092	
Yield/plant		-0.0344	
2. Days to maturity	0.0653		0.0163
Indirect effect via:			
Days to 50% flowering		-0.0107	
Plant height		0.0070	
Primary branches		0.0001	
Secondary branches		0.0134	
Pods/plant		0.0005	
Seeds/plant		0.0078	
20 seed weight		-0.0003	
Yield/plant		-0.0667	
3. Plant height	0.0318		0.0334
Indirect effect via:			
Days to 50% flowering		-0.0028	
Days to maturity		0.0143	
Primary branches		-0.0004	
Secondary branches		0.0320	
Pods/plant		0.0006	
Seeds/plant		0.0085	
20 seed weight		0.0469	
Yield/plant		-0.0976	
4. Primary branches	-0.0026		0.0155
Indirect effect via:			
Days to 50% flowering		-0.0013	
Days to maturity		-0.0023	
Plant height		0.0053	
Secondary branches		0.0522	
Pods/plant		0.0003	
Seeds/plant		0.0047	
20 seed weight		-0.0063	
Yield/plant		-0.0344	

Table 16 (contd.)

Pathways	Direct effect	Indirect effect	Correlation coefficient
5. Secondary branches	0.0837		0.0161
Indirect effect via:			
Days to 50% flowering		-0.0035	
Days to maturity		0.0105	
Plant height		0.0122	
Primary branches		-0.0016	
Pods/plant		0.0008	
Seeds/plant		0.0115	
20 seed weight		-0.0006	
Yield/plant		-0.0968	
6. Pods/plant	0.0013		-0.0531
Indirect effect via:			
Days to 50% flowering		-0.0041	
Days to maturity		0.0257	
Plant height		0.0153	
Primary branches		-0.0007	
Secondary branches		0.0519	
Seeds/plant		0.0191	
20-seed weight		-0.0094	
Yield/plant		-0.1523	
7. Seeds per plant	0.0198		-0.0649
Indirect effect via:			
Days to 50% flowering		-0.0045	
Days to maturity		0.0257	
Plant height		0.0137	
Primary branches		-0.0006	
Secondary branches		0.0488	
Pods/plant		0.0012	
20-seed weight		-0.0187	
Yield/plant		-0.1503	
8. 20-seed weight	0.1351		0.0918**
Indirect effect via:			
Days to 50% flowering		0.0013	
Days to maturity		-0.0002	
Plant height		0.0111	
Primary branches		0.0001	
Secondary branches		-0.0004	
Pods/plant		-0.0001	
Seeds/plant		-0.0027	
Yield/plant		-0.0524	

Table 16 (contd.)

Pathways	Direct effect	Indirect effect	Correlation coefficient
9. Yield/plant	-0.1734		-0.0289
Indirect effect via:			
Days to 50% flowering		-0.0038	
Days to maturity		0.0251	
Plant height		0.0179	
Primary branches		-0.0005	
Secondary branches		0.0468	
Pods/plant		0.0011	
Seeds/plant		0.0172	
20-seed weight		0.0408	

DISCUSSION AND CONCLUSION

5. DISCUSSION AND CONCLUSION

5.1. Experiment 1

5.1.1 Mean Yields

This experiment was conducted to determine the relationship among the F2 to F6 generations for the mean yield and other characters like days to 50% flowering and maturity, plant height, numbers of primary and secondary branches, numbers of pods and seeds per plant, 20-seed weight and yield per plant. Analysis of variance was done to determine whether there were significant differences among the mean yields of the crosses and check varieties. Correlation studies were also carried out to find the relationship among the five generations.

There were significant differences among the treatments. The F2 and F3 of RSG 44 x Phule G-7, the F3 and F6 of JG 1265 x Phule G-7, the F3 of 2375 x JG 315 and some other crosses had significantly higher mean yields than Annegeri and BDN 9-3 (check varieties). But none of the crosses had significantly higher mean yield than the check variety K 850 (Table 5). The crosses were compared for their performance in each generation. The results showed that there were no significant differences among the mean yields of the crosses in F2 and F6 generations while there were significant differences among the mean yields of the crosses in the F3, F4 and F5 generations (Table 5). The cross RSG 44 x PhuleG-7 which was one of the highest yielders in the present experiment was one of the highest yielders among the twenty three crosses tested in 1984 F3 yield trial at ICRISAT Center (data obtained from Chickpea Breeding sub-program, ICRISAT).

Switching of the rank was observed for all the crosses in different generations except in case of RSG 44 x Phule G-7 which ranked consistently first in F2, F3 and F4 generations. Switching resulted in significant differences among the mean yields of different generations of the crosses JG 1265 x 2375, JG 1265 x Phule G-7, ICCC 6 x JG 315 and 2375 x JG 315 (Table 5). The remaining crosses had no significant differences among the mean yields of their progenies in different generations.

These results showed that the crosses did not perform consistently. It appears therefore that no reliable predictions can be made about the performance of the later generations from F2 or F3 replicated yield trial. Dahiya et al (1983b) found switching between high and medium and medium and low yielding groups but in the present experiment switching between high and low yielders was also observed. For instance Phule G-12 x 64-3 which was in eighth rank in F2 and ninth in F3 generations, ranked second in F4 and third in F5 and fifth in F6. Similarly, the crosses JG 1265 x Phule G-7, Phule G-12 x 2E and some others showed such switching of rank. Such lack of consistency between mean yield of bulk population and mean yields of the F5 lines selected from the crosses were reported in soybean by Weiss et al (1974). They also reported a lack of agreement between the performance of the crosses in different generations tested in the same year or the same generation tested in different years. This could be due to sampling in each generation which can reduce genetic variability besides natural selection operating in the population that may also modify gene frequency in an undesirable direction (Empig and Fehr, 1971).

When the mean yields of the crosses of the five generations were compared, there were no significant differences between the mean yields of RSG 44 x Phule G-7, JG 1265 x Phule G-7, Phule G-12 x 2E, 2375 x JG 315, Phule G-12 x 64-3 and 64-3 x BDN 9-3 (Table 5). The crosses RSG 44 x Phule G-7 and JG 1265 x Phule G-7 were among the heighest yielders in the 1984 F3 yield trial. A cross 64-3 x BDN9-3 which was the lowest yielder in 1984 F3 yield trial was found to rank fourth whereas JG1265 x 2375 was ninth in rank (Table 5). The cross JG 1265 x 2375 was among the best yielders in 1984 F3 yield trial.

The lowest average yield was obtained from Annegeri (one of the standard check varieties). This variety had poor germination, but filling was done promptly. Probably, the low yield could be attributed to the inability of the late sown plants to give as high yield as others in the same plots. The F4 generation of Phule G-12 x 64-3 and the F5 generations of ICCC6 x JG315 and JG1265 x 2375 were also among the poorly performing entries (Table 5). Generally, when the yields of crosses were compared across generations RSG44 x Phule G-7 and JG1265 x Phule G-7 appeared to be more stable. Dahiya et al (1983b) also found the cross F-61 x T-3 to rank top in F2, F3 and F4 at Hisar. The reason could be due to slow change in the population structure, since a population handled as a bulk for a few generations changes very slowly unless there is a high degree of selection pressure eliminating the poor competitors (Empig and Fehr, 1971). Such stagnation occurs especially for quantitatively inherited traits, where significant shifts in the mean do not usually occur until about 15th generation (Suneson, 1956).

5.1.2 *Correlation coefficients among the yields of F2 to F6*

The correlation analysis among the F2 to F6 generations revealed a significant positive correlation (r = 0.674*) between F2 and F3 (Table 6) indicating that F2 yield testing can help to predict the performance of the crosses in the F3 generation. Dahiya et al (1983b) also found that the seed yield of the early generations (F2, F3 and F4) was effective in identifying best crosses and recommended this procedure as a basis for rejection of poor performing crosses. Bhuller et al (1977) indicated that the F2 yield data could reliably be used for identifying crosses of high yield potential while the F1 data appeared to be of no value for predicting yield in the subsequent generations. Similarly, Nass (1979) recommended mid parental yield, F1 yield and F2 yield tests as a progressive set of screening tests for a given set of crosses to effectively maintain the superior ones in the breeding program of wheat. Interestingly, the F3 generation which had strong associations with the F2 generation, had no significant positive associations with F4 (0.0380), F5 (0.2108) and F6 (0.4311) generations. These results suggest that F2 replicated yield trial is a reliable predictor of the crosses performance in F3 and can be used to eliminate the poor performing crosses. But the F2 or F3 generation yield test could not be used to predict the performance of the later generations (F4, F5 and F6). Knott and Kumar (1975) and Dahiya et al (1983b) recommended F2 yield test of bulks to give an indication of the potential of the crosses.

The strong association between F2 and F3 generation could be attributed to less switching among the crosses or the stability of the performances of the crosses in these two generations. This can be illustrated by the performances of the crosses RSG44 x Phule G-7, 2375 x JG 315, JG1265 x 2375 and Phule G-12 x 64-3 (Table 5). In these two generations, RSG 44 x Phule G-7 was found to rank first while 2375 x JG-315 was second in F2 and third in F3 generations. Similarly, JG1265 x 2375 stood sixth in both generations while Phule G-12 x 64-3 was eighth in the F2 and ninth the F3 generations.

Similar results (r=0.313 and 0.543) were also obtained by Mckenzie and Lambert (1961) between F3 and their related F6 lines in two barley crosses. The F2 generation showed no significant correlation with F4, F5 and F6 generations indicating that there is no erroneous effect if this procedure is used wherever it is felt to be useful. If these five generations were grown in different seasons, the switching of their positions could have been attributed to the genotype x environment interaction as it was considered by O'Brien et al (1978). However, this procedure can be used in the present experiment to eliminate the poor yielding crosses in F2 generations, because the upper top yielding crosses in F2 were found to remain the best yielders in F3 and had also the highest mean yields of the five generations (Table 5). Similar recommendations were also made by Harrington (1940), Sikka et al (1959), Smithson (1985), Allard (1960) and Knott and Kumar (1975). This is because the F2 generation yield test as bulk can be used to indicate the potential of the crosses to concentrate efforts on the high yielding population in the later generations. Allard (1960) recommended to limit the use of this procedure to truncated selections in which only the poorest lines are to be eliminated, and he indicated that the F3 or F4 performance measured in single trials has generally been a poor basis for predicting the yields of the subsequent selections and thus trials conducted in more than one location have been moderately good for purpose of prediction. Mckenzie and Lambert (1961) suggested that early generation yield testing would not be suited for the crosses between varieties differing very little in their yield potential, but according to them it seems more likely to be useful in crosses where there is a wide range in the yield of the segregates. Allard (1960) also indicated that despite the care with which parents are chosen, it is a common experience to find that certain combinations to produce many superior offsprings, and other hybrids betweeen apprently equally promising parents produce disappointing progeny. This was attributed to the combining ability which often depends on complex interaction systems among genes. This could be true for the crosses used in these experiments since all of them are short duration cultivars. Cregan and Busch (1977) also found early generation testing to be effective in identifying those crosses from which the highest yielding lines might be expected particularly if the F2 bulk test would be done. Probably this could be due to the ability of the F2 mean yield to predict the performance of the next generation('s) as the F2 exhibited a significant correlation in this experiment.

Tapsell and Thomas (1986) also found prediction to be effective in F3 family analysis of the barley crosses so that the best crosses could be advanced towards homozygosity and selection could be carried out in the later generations with more resource concentrated on the better crosses. Leffel and Hanson (1961) also found the performance of the parents or their crosses in early bulk generation test as reliable predictors of the performance of lines obtained from their crosses in the F3 generation in soybean. These findings are not similar to the results obtained in the present experiment because the F3 generation did not show significant association with the later generations (Table 6). The disadvantage of an early generation yield test could be the elimination of the populations with lower mean yields but with large variances and thus some crosses with the potential of producing high yielding lines may be discarded as reportd by Cregan and Busch (1977). This aspect was not considered in this experiment since the ultimate goal was to determine the effectiveness of early generation yield testing to predict the performance of crosses in the later generations.

The best procedure proposed by Knott and Kumar (1975) was to minimize or eliminate yield testing in early generations and concentrate on it in later generations when reasonable homozygosity has been attained. But the results of this experiment showed no significant associations of F4 and F5 yield with the F6 generation yield. These relationships indicated that yield testing at later generations could not be of value to identify the best crosses. The F2 and F3 had very low correlations with the F4, F5 and F6 generations. Knott and Kumar (1975) also obtained such low correlations between F3 and F5 yields. The reason given by Knott and Kumar (1975) was that the yield was affected by a large number of genes having small effects, then most of the plants in any F3 line will carry close to the average number of genes for yield present in that line. Hence, a few non representative F5 lines used in the correlations will have little effect. Empig and Fehr (1971) attributed such lack of agreement between performance of crosses in different generations to reduced genetic variability besides natural selection. The randomly sampled seeds from the bulk of each generation might have also attributed to such low correlation. This could have also been reduced if equal numbers of pods and/or seeds were taken from each plant while advancing the generations.

Welsh (1981) suggested that early generation testing could be valid in identifying crosses with good probabilities of high number of best yielding selections if each population has approximately the same distribution pattern. Similar to this finding, Virupakshappa (1984) also obtained no significant inter-generation correlations between F2-F3, F3-F4, and F5-F6 generations of two cowpea crosses.

The poor inter-generation association in chickpea for pods per plant and grain yield was reported by Rahman and Bahl (1986). This was attributed to year and agronomic effects, including plant population which had a pronounced effects on such association. All the entries in the present experiment had an excellent plant population since double seeds were initally planted per hill and then thinning of the weakest seedlings was done after germination of the two seeds. Secondly, the field used for this experiment had never been planted to chickpea and thus no symptoms of soil borne diseases were observed. The only serious problem was the high incidence of pod borer for which several sprays of insecticide were applied during the development of flowers and pods. But Whan et al (1981) planted all the generations of wheat from the F2 to F5 together in one season as it was done for this experiment and obtained the correlations values of 0.51** for the F2 line / F3 mean 0.68** for the F3 line/ F4 mean and 0.78** for the F4 line / F5 mean. The strategy proposed by Sampson (1972) was to choose the best yielding progenies on the basis of early generation means and to follow by selecting superior lines within those good yielding progenies. Hence, if the high yielding crosses such as RSG 44 x Phule G-7 and JG1265 x Phule G-7 were selected by early generation yield test as in the present experiment they could be used as the sources of superior progenies in the later generations.

The efficiency of the early generation yield testing in F2 to predict the performance of the crosses in F3 generation appeared to be high in this experiment since these two generations had significant correlations between themselves (Table 6). But, the results obtained by Knott and Kumar (1975) in wheat indicated that single seed descent (SSD) method was more efficient than the early generation yield testing. They recommended that the F1 or F2 generations of crosses should be yield tested as bulks to indicate the potential of the crosses. The selected material should then be carried to at least the F5 by the single seed descent (SSD) procedure to overcome the inadequate sampling problems in each generation which can reduce genetic variability. Boerma and Cooper (1975c) also found similar results when they compared the SSD method with early generation yield testing and pedigree procedures. The results obtained by Chaudhary et al (1978) indicated that the selection of a cross for its breeding potential in chickpea should be based on the combining ability of the parents as well as on the relative F1 and F2 performance. Similarly, Dahiya et al (1984) compared the efficiency of early generation yield testing, visual selection and random selection in chickpea and found that early generation yield testing was more efficient than the other two methods.

5.1.3. Correlation coefficients among F2 to F6 for different characters

The relationship among the F2 to F6 generations were also determined for different characters (Table 7). Significant and positive correlations were obtained between F2/F3 (0.7025**), F3/F4 (0.5513**), F4/F5 (0.4224**) and F5/F6 (0.3867**) generations for days to 50% flowering indicating that prediction can be made from the F2 or F3 generation to identify the crosses that will require different number of days to flower. Similarly, days to maturity had significant positive association among F2/F3(0.6504**),F3/F4(0.5982**)and F4/F5(0.6635**) indicating that a prediction from early generation can be made for this character to identify crosses with desirable days to maturity.

There was no significant relationship among the F2 to F6 generations for characters such as plant height, primary branches, secondary branches, pods per plant and seed per plant (Table 7). Rahman and Bahl (1986) also found similar results for pods per plant and grain yield. These lack of associations were attributed to years and agronomic effects, including plant population which had a pronounced effects on such association. According to them making selection for high yield or high pod number in early generations will be of little or no value since genetic differences are masked by genotype x environment interaction.

The F2 generation had a positive and significant correlation with the F3 (0.4136**) and the F4 (0.3059**) while the F3 had also significant positive correlation (0.2682**) with the F4 for seed weight (Table 7). Similarly, the F4 was positively correlated (0.2093*) with F5 whereas the F5 had a significant and negative association (-0.2267**) with F6 generation. Interestingly, only the F3 generation exhibited a positive and significant correlation with the F4 for yield per plant while significant and positive association was only between F2 and F3 generations for mean yield per plot (Table 6 & 7). This indicates that yield per plant and yield per plot have no influence on each other. Other generations had no significant relationship with each other. Johnson et al (1955b) found early generation testing to be effective in identifying characters such as a long fruiting period, lateness, heavy seed, resistant to shattering, and high oil content but not for grain yield in soybean. Voigt and Weber (1960) also found the early generation yield testing method to be similarly useful in identifying characters such as maturity and height and superior or equal in lodging resistance to those selected by the bulk and pedigree breeding methods. Similarly, Tapsell and Thomas (1986) found early generation selection to be effective in identifying reduced plant height as no lines were found to be taller than their taller parents. The high estimate of inter generation correlation between the F3 and F4 generation and the consistency of this association for plant height in chickpea was attributed to highly heritable nature of characters which are less influenced by environmental changes (Rahman and Bahl, 1986).

5.1.4. Correlation coefficients among different characters.

Correlation estimated among yield components in each of F2, F3, F4, F5 and F6 generations separately indicated that primary branches had positive associations with all the characters (Table 8). This character had particularly significant positive correlations with number of pods per plant in F2 (0.5523**), F3 (0.3207**), F4 (0.2789**), F5 (0.5747**) and F6 (0.4576**) generations. It also showed significant correlations with yield per plant in all generations. Such association between primary branches and seed yield per plant was reported by Sandhu and Singh (1970), Singh et al (1978), Adhikari and Pandey (1982a) and Tyagi et al , (1982) and Shahi et al (1984). Days to 50% flowering and maturity have shown from significant negative to no correlation with seed yield per plant. Setty et al (1977) also reported negative correlations between days to flowering and yield per plant and days to maturity and yield per plant. Seed yield had a significant positive correlations with plant height, primary branches, secondary branches, pods per plant, seeds per plant and seed weight in almost all the five generations (Table 8). Secondary branches had positive association with number of pods and seeds per plant. It had also positive correlation with seed yield per plant in all the generations. Dahiya et al (1986) and Naidu et al (1986) also found that the number of fruiting branches is the most effective selection criterion.

Number of pods had significant correlations with all the characters in F4 except 20 seed weight. Similar associations were observed when combined data of F2 to F6 generations were analyzed (Table 9). It had significant correlations with number of primary and secondary branches and seeds per plant in F3, F5 and F6 generations (Table 8). The highest correlation values were obtained in all generations between number of pods per plant and yield per plant indicating that the number of pods per plant is the most effective selection criterion in chickpea. This character was followed by the number of seeds per plant and secondary branches (Table 8 and 9). Tomar et al (1982), Ram et al (1980), Khan and Chaudhary (1975) and Salimath and Bahl (1983) also found a strong relationship of yield per plant with number of pods and number of seeds per plant. Ram et al (1980) recommended the number of pods per plant and number of seeds per plant as effective measures of yield in F2's and F3's of chickpea. These two characters showed the maximum direct effect consistently in all the crosses of their studies.

Seed weight was also one of the important component of yield per plant, but in most of the cases it was negatively correlated with number of pods per plant and number of seeds per plant. Mishra et al. (1974) found similar negative correlations between number of seeds per plant and seed weight. Khan and Chaudhary (1975) obtained negative correlation between seed yield per plant and seed size and also seed yield per plant and number of seeds per pod. This negative relationship between seed yield per plant and seed size was not observed in the present studies (Table 8 and 9). The correlation estimated among these characters in combined F2, F3, F4, F5 and F6 generations revealed that there were significant negative correlations between 20-seed weight and days to flowering and days to maturity and seeds number per plant (Table 9). The association between plant height and days to maturity and between 20-seed weight and number of pods per plant were not significant. Generally, seed yield had strong correlation with the number of pods per plant (0.5159** to 0.8513**) and number of seeds per plant (0.3894** to 0.8441**). Therefore, the present results suggest that a combination of these characters namely number of pods, number of seeds, primary and secondary branches to be strong selection criteria for the single plant selection in segregating populations. This result also suggests that emphasis should be given to the seed weight during selection since it had a highly significant association with seed yield per plant. Bisen (1985b) also found that selection for seed size was efficient until the optimum level of seed size is obtained and later the seed size and seed yield show negative correlation in chickpea. This was attributed to a decrease in the variability of seed size during continuous selection process which may not give further scope for selection.

5.2. Experiment II

5.2.1. Mean yields of the entires

Selection was made in 1985/86 crop season from the nine crosses of F4 generation planted in two spacings. During selection, the plants in the close spacing were so much reduced particularly in number of branches, number of pods per plant and in overall vegetative growth as compared to those planted in a wide spacing. The seeds of selected plants were sown in 1986/87 crop season and the effects of the spacing on the performance of F5 progenies were analyzed. Thus the analysis of variance carried out to assess the differences in the two spacings based on the data of their F5 progenies showed significant differences between the means of two spacings for days to 50% flowering and grain yield per plot (Table 12). The interaction between spacing and family was also found to be significant for days to 50% flowering and days to maturity. This interaction was not significant for grain yield per plot (Table 12). There were significant differences between the mean yields of the spacings in the families of 64-3 x BDN9-3, Phule G-12 x 2E, Phule G-12 x 64-3, RSG44 x Phule G-7, JG1265 x Phule G-7 and JG1265 x 2375 while no significant differences were obtained in the families 2375 x JG 315, ICCC 6 x 2375 and ICCC 6 x JG315. This indicated that the last three crosses are not influenced much by change in spacing environment.

When the means of the two spacings were compared for yield components, days to flowering and maturity were not severely affected by the spacing, but the effect of spacing was pronounced on number of secondary branches, number of pods per plant, number of seeds per plant and yield per plant. The 20-seed weight was the same in both spacings (Table 11). Singh and Yadav (1985) also found that the variation in seed rate did not change the seed weight. Sen and Jana (1960) found no effect of different spacings on chickpeas' plant height except the lowest spacing exhibited shorter height. Of all the components of yield affected by the spacing , the number of pods per plant and number of seeds per plant were severely reduced (Table 11). Similarly, Shaktawat and Sharma (1985), Singh and Yadav (1985) and Saxena and Sheldrake (1979) found increased seed rates to cause significant reduction in the number of pods and grain yield per plant. Sen and Jana (1960) also reported that the wider spacing gave larger number of total branches and resulted in a greater number of pods which helped increase the yield per plant. They also found the least number of fruits, reduced seed weight and the highest percentage of seedless pods. The results obtained by Penaloza (1986) revealed that branch number per plant was reduced by increased plant density, while secondary branches were most affected similar to the results obtained in this experiment. The individual plant yield was highest when chickpeas were sown in the widest spacing (Sen and Jana, 1960). Similarly the highest seed yield of 56 gm per plant was obtained from wide spacing as compared to 22 gms per plant from close spacing in the present experiment (Table 11). Saxena and Sheldrake (1979) observed suppressed branching of a normal cultivar when it is grown at high population densities, and a normal branching type tailors itself into a non branching type. This shows that the characters such as number of branches per plant, number of pods per plant, number of seeds per plant and yield per plant are highly influenced by spacing.

Bisen (1984) compared three breeding procedures and found that varying spacing did not influence the results of the different breeding procedures. The results obtained by Bisen et al (1983, and 1985b) further confirmed that fertility and spacing have no influence on the efficiency of any selection procedure indicating that selection under any spacing environment is equally good. The variation due to spacing showed significant differences for number of pods, number of seeds and hundred seed weight (Bisen et al, 1985a). However, they found that interaction due to spacing and breeding methods (spacing x breeding) were significant for the characters such as number of pods and seeds per plant and hundred seed weight and seed yield per plant. This could probably be attributed to the instability of these characters under different environment to use them as selection criteria. When the means of these characters were compared for two spacings, a marked effect of the spacing was clearly observed indicating that the wider spacing favours the development of these characters.But, when the mean yields of different spacings were compared within an individual family, there were statistically significant differences between the two spacings in most of the families (Table 12). For instance, the mean yield of 3177 kg/ha of wide spacing was significantly higher than 2697 kg/ha obtained from close spacing in the family 7.

Although the differences were not significant within all the families, there was no family which had mean yields of close spacing greater than the mean yields of the wider spacing (Table 10). Spacing was not found to have significant effect on days to maturity. The yield per plant was also higher in a wide spacing by about three times of the yield per plant in a close spacing (Table 11). This could also be attributed to the highly reduced number of pods, seeds and secondary branches per plant which have strong positive correlation with yield per plant (Table 13). Seed weight was found to be similar in both spacings indicating that selection for this character can be made under any spacing.

The mean yields of the progenies of each spacing within family were compared with the mean yield of the F5 bulk of each family and the results showed that higher number of progenies that yielded better than the bulk F5 were from the wide spacing (Table 10). In a family RSG 44 x Phule G-7, there was not a single progeny of the plants selected from close spacing that gave a better yield than the bulk F5 (check). Three progenies of the same family of the plants selected from wide spcing gave a better yield than the check bulk F5. The highest yield (4915 kg/ha) in this experiment was obtained from one of the progenies of the plants selected from wide spacing in the family of RSG 44 x Phule G-7 (Table 10). The second highest yield (4823 kg/ha) was obtained from a progeny of plant selected from close spacing of a cross 2375 x JG 315. These two lines were not the ones having the highest number of branches, pods, seed and seed yield per plant when compared to other lines. For instance, the highest yielder had a plant height of 41 cm, 8 primary branches, 16 secondary branches, 99 pods and 99 seeds per plant, 6.1 gm of 20 seed weight and 29.2 gm of yield per plant. These figures were low as compared with the range of these characters obtained for the overall selected plants (Table 11). Interestingly, the two crosses which produced the highest yielding lines were also the highest yielders in experiment I. This indicates that the highest yielding lines can be selected primarily from the highest yielding crosses in early generation yield test in replicated trial. Therefore, the F2 yield test can be used as reliable predictor of the crosses from which the highest yielding lines can be produced. However, the highest number of progenies that yielded at least more than 3000 kg/ha were selected from crosses ICCC 6 x JG 315, JG 1265 x 2375, JG1265 x Phule G-7 and Phule G-12 x 2E. There were statistically significant differences among the entries in these crosses. This also shows that the highest yielding crosses on the basis of early generation yield test do not necessarily give a large number of high yielding lines.

When the mean yields of the selected plants were compared to the mean yields of the randomly picked plants within individual family, selection from close spacing did not show any advantage over randomly selected plants. However, selection from wide spacing gave an advantage of 20%, 7%, 9% and 8% over random selection in the families of Phule G-12 x 2E, JG1265 x Phule G-7, JG1265 x 2375 and ICCC 6 x 2375 respectively. Of these an advantage of 20% was statistically significant as compared to others. The efficiency of selection was about the same to that of random selection in the families of 64-3 x BDN9-3 and ICCC 6 x JG 315. This shows that selection efficiency is also determined by the type of crosses. The poor efficiency of selection in these two families could be due to more similarities of the parents involved in the crosses. The hybrids between apparently equally promising parents were reported to produce disappointing progeny (Allard, 1960). If this is true, it implies that the efficiency of selection will increase as the differences between the parents involved in the crosses become wider.

Days to 50% flowering and maturity were in the range of 42 to 52 and 95 to 106 days for all the plants selected from the F4 generation in 1985/86 (Table 11). These days to 50% flowering and maturity were the average of the segregating populations on a plot basis. But, when the single plant selections were sown in the F5 progeny rows in 1986/87, their days to 50% flowering and maturity ranged from 34 to 60 and 77 to 104 days, respectively (Table 10). This indicates that the average number of days to 50% flowering and maturity on population basis does not necessarily show the true value of days to 50% flowering and maturity for the single plant selections. The lines that were early to flower and mature gave relatively low yields as compared to those of late maturity group. However, this does not hold true for all the selections since there were some exceptions from both the early and late groups. These late lines had relatively more pods and seeds per plant in the F4 generation.

When selection was made in 1985/86, the plants with the highest number of pods per plant had also the highest number of seeds per plant. This was mainly because the number of pods per plant was significantly correlated with the number of seeds per plant. Among the selections, plant No.2 of the family 1 selected from wide spacing, plant No. 1 and 25 of the family 2 selected from wide spacing, and plant No.12 and No. 16 of the family 8 selected from wide spacing had the highest number of pods and seeds per plant. These were 200, 274, 203, 217 and 220 pods per plant and 203, 290, 202, 252 and 250 seeds per plant. These progenies gave the yield of 3236 kg/ha, 3202 kg/ha ,3102 kg/ha, 3938 kg/ha and 2977 kg/ha, which were relatively low as compared to the yield of the other progenies. This shows that the high number of pods and seeds per plant does not necessarily indicate the performance of the progeny in the F5 generation. The seed yield per plant was not found as a good selection criterion in the F4 to indicate the yield potential of the F5 progenies. The highest number of secondary branches recorded in the F4 did also not indicate the performance of the F5 progenies. Generally, the plants which had the highest numbers of primary and secondary branches, pods and seeds per plant and seed yield per plant in the F4 were not found to be the highest yielders in the F5 yield test. But these characters were reported to be the most essential components of the yield. However, the plants which had high 20-seed weight were in most cases found to be the highest yielders.

5.2.2. *Correlation coefficients for yield and yield components*

The correlation studies carried out to determine the relationships' between yield per plot and yield components and among these characters themselves revealed that yield per plant was strongly correlated with days to 50% flowering, days to maturity, plant height, number of primary and secondary branches per plant, number of pods and seeds per plant and 20-seed weight (Table 13). The 20-seed weight was found to be negatively correlated with all the characters except with plant height and seed yield per plot. The correlation values between 20-seed weight and seed yield per plant were 0.5411** and 0.6249** in close and wide spacings. This character showed significant negative correlation with seed number per plant. Gill and Brar (1980) considered these characters as some of the economic traits because these characters are the major components of the yield per plant . Baluch and Soomro (1968) and Sharma et al (1969) also reported that pods per plant and seed weight had significant positive correlations with seed yield per plant. Sandhu and Singh (1970), Rang et al (1980), Khorgade et al (1985), Setty et al (1977) and Singh et al (1978) obtained positive correlations between seed yield per plant and number of primary and secondary branches and pods per plant. Singh et al (1978) indicated that selection based on high pod and primary branch number and a low secondary branch number would be effective to improve chickpea yield. But, the results obtained from the present experiment revealed strong associations of seed yield with number of pods per plant (0.5026** - 0.8770**) number of seeds per plant

(0.4382** to 0.8664**) and secondary branches (0.0893** to 0.5584**)per plant (Tables 13,14 and 15). This indicates that improving number of pods, seeds and secondary branches simultaneously will directly increase the yield per plant. Khorgade et al (1985) found 100-seed weight and number of total branches per plant as the most important yield determiners. Days to 50% flowering and maturity had also positive and significant correlations with yield per plant when the analysis for combined data of two spacings was made (Table 13). However, these characters showed no significant association with seed yield per plant in a close spacing and a wide spacing (Table 14 and 15). Number of pods per plant was found to be positively correlated with the number of primary and secondary branches, plant height and number of seeds per plant (Table 13,14 and 15). But, Adhikari and Pandey (1982a) found a significant and negative (-0.95) correlation between plant height and pods number per plant. Islam et al (1982) found also a negative relationship between seed yield per plant and plant height which is contrary to the results of the present study.

Similar studies were carried out by Dahiya et al (1986), Naidu et al (1980), Tomar et al (1982) , Ram et al (1980) and others in a segregating population and most of the findings showed that seed yield per plant was positively correlated with the number of pods and seeds per plant. After comparing different selection criteria, Dahiya (1986) recommended to use the number of fruiting branches as the criterion to increase seed yield in chickpea. Ram et al (1980) found out that the number of pods per plant and seeds per plants as effective measures of yield in the F2 and F3 generation of chickpea . These findings are similar to the results obtained in the present experiment. These characters which are considered as important yield components showed no significant correlations with seed yield per plot unlike the seed weight which had a significant correlation value of 0.0918** (Table 13) The number of pods per plant and number of seeds per plant which were considered as selection criteria in chickpea had no significant correlation with seed yield per plot (Table 13,14 and 15). Since the observation on these characters were collected from the single selected plants in F4 in 1985/86 and the yields per plot were obtained from F5 progenies sown in 1986/87, probably, the effect of different environment of the two seasons might have masked the expected relationship between these characters and yield per plot. Probably, the use of more replications for testing the F5 progenies would be useful to increase the precision and thus permit the breeder to realize these relationships. But the amount of seeds obtained from single plant selection in F4 may not enable breeders to grow them in a more replications. However, reliable selection criterion in the F4 is very essential to help the breeders predict the performance of the F5 progenies.

5.2.3. Path coefficient analysis of yield components

The path coefficient analysis for combined data of two spacings was carried out to determine the direct and an indirect effects of yield components. The path coefficient analysis was not done separately for close and wide spacings since all the characters had no significant correlation with yield per plot (Table 14 and 15). The results showed that 20-seed weight is the major direct' positive contributor to the seed yield per plot. Twenty seed weight had the lowest an indirect positive contribution via days to 50% flowering, plant height and primary branches. It had also an indirect negative effect via days to maturity, secondary branches, pods per plant, seed per plant and yield per plant (Table 16). Adhikar and Pandey (1982a) and Khan et al (1983) also found 100 seed weight to contribute most directly to the seed yield per plant. This is further supported by the work of Asawa and Tiwari (1976) who found seed weight as one of the major contributors positively and consistently in all their three populations. Yield per plant had significant positive correlations with all the characters studied in this experiment but showed no associations with seed yield per plot (Table 13). The maximum overall direct contribution to yield per plot was obtained from 20-seed weight which could be due to lesser influence of the spacing environments on this character (Table 11). However, significant correlation between 20-seed weight and yield per plot was not obtained when correlation was carried out separately for the two spacings.The characters such as number of pods, number of seeds per plant and yield per plant were also found to be severely influenced by the environment (Table 11) and thus may not be good criteria to predict the performance of the F5 progenies selected from F4. This result also showed that the plants which had the highest number of pods and seeds per plant were not found to give higher yield (example plant No.1 in the Family 64-3 x BDN9-3 selected from wide spacing).

Generally, the correlation and path analysis revealed that the seed weight may be useful to predict the performance of the F5 progenies better than other characters. Jain et al (1981), Katiyar and Singh (1978) and Pandya and Pandey (1980) found the seed weight as one of the effecive selection criteria in chickpea. Asawa (1974) recommended to give due consideration to the seed weight. The characters such as number of pods and seeds per plant and yield per plant were not found to be important since they are highly influenced by the environment. Muehlbauer et al (1985) also did not emphasise on yield component as means of selecting improved lines in lentil because the components involved such as degree of branching and fruit number are influenced markedly by agronomy and environment and thus vary from year to year and location to location even for the same genotype.

5.3 Conclusions

The conclusions that can be drawn from these results are:-

1. The F2 bulks replicated yield trial can be used to predict the performance of the crosses in F3 generation. This yield test at F2 can be used to discard the poor performing crosses allowing more efforts to concentrate on the crosses of high yield potential in the later generations.

2. The highest yielding progenies were selected from the highest yielding populations in replicated yield test of F2 and F3 generations.

3. To study the relationship between F2 and later generations single seed descent (SSD) method may probably be better suited to avoid the problem of sampling and truncation of variability in each generation.

4. From a F2 yield test it is possible to predict days to 50% flowering and maturity and seed weight in later generations.

5. Yield per plant had significant positive association with the number of pods and seeds per plant, number of secondary branches and 20 seed weight in all generations, but the correlation values increased from F2 to F5 and then stablized.

6. Spacing had significant effect on single plant selection in F4 and on performance in F5 progenies. But different crosses responded differently to the spacing environment.

7. Wide spacing gave better opportunity to select high yielding progenies.

8. Selection based on 20 seed weight in F4 would probably be effective to predict the yield performance of the progenies in F5 generation. Therefore, selection from wide spacing using seed weight as selection criterion in F4 may give better scope for chickpea improvement.

6. SUMMARY

Two experiments were carried out to determine 1) the relationship among the performances of F2 to F6 generations in chickpea and 2) the effect of different spacings in F4 populations on the performance of single plant selection in F5 progenies. The study was also made to estimate the association between yield and yield components in segregating population of chickpea and to establish criteria for single plant selection.

1. The results of the experiment revealed that the F2 had a significant positive correlation with the F3 generation but no significant correlations with all the other generations. The F3 generation yield showed positive but non significant relationships with the F4, F5 and F6 generations. The F4 and F5 seed yields had non-significant negative correlations with the F6 generation. The strong correlation between the F2 and F3 indicates that under near equal conditions F2 yield testing can be used to predict the performances of F3 generations. Cross RSG-44 x Phule G-7 was first in rank in the F2, F3 and F4 generations, and also had the highest significant mean yield over the five generations.

2. Among the F2 to F6 generations significant positive correlations existed for days to 50% flowering and days to maturity except for the non-significant F5/F6 correlation. There were also significant and positive correlations between the F2 and F3, F2 and F4, F3 and F4, and F4 and F5 generations for 20 seed weight, but the F5 had significant and negative correlation

with the F6. These results indicate that from early generation tests it is possible to predict the days to 50% flowering,the days to maturity and the seed weight of the crosses in the later generations. Correlations among the F2 to F6 generations for characters like plant height, number of primary and secondary branches, number of pods per plant, number of seeds per plant and seed yield per plant were not significant. This shows that prediction from early generation test can not be made for these characters, and that these characters are not stable from generation to generation even in one season and one experiment.

3. Yield per plant had strong positive association with number of pods and number of seeds per plant, seed weight, number of primary and secondary branches and plant height. Most of these characters had positive association among themselves in all the five generations. Yield per plant exhibited significant negative associations with days to flowering and maturity in F2 while it had no significant association in other-generations.

4. Study of the effect of different spacings on the performance of single plant selections in F5 progenies indicated that there were significant spacing effects. Selection from wide spacing (60cm x 20cm) gave better progenies than selection from close spacing (30cm x 10cm). Selection from wide spacing gave advantages of 0-20% and 9-28% over random selection and selection from close spacing. The efficiency of selection differed among the crosses. Selections from close spacing had no advantage over plants taken at random.

5. From the study of relationships between yield per plot and yield components it was found that yield per plot had a positive and strong correlation with 20-seed weight, but no significant association with other characters, and therefore only seed weight could probably be used as a selection criterion in the F4 to predict the performances of the F5 progenies.

6. The path coefficient analysis showed that the seed weight had the largest direct contribution to yield per plot above all the other characters. All the remaining characters had no significant contribution to yield per plot. Therefore, more emphasis may be given to seed weight when making selection.

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VITA

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I was a coordinator of the national chickpea and lentil research programs in Ethiopia. Since 1977 I have released two chickpea and three lentil varieties. I recommended two other chickpea varieties in March 1984 and they were released in 1986.

In 1979(January to June), I have been at the International Center for Agricultural Research in the Dry Areas (ICARDA) for 6 months training in chickpea and lentil breeding programs. In 1983, I also participated in the training courses on "Induction and Uses of Mutation in Plant Breeding" at the International Atomic Energy Agency (IAEA) Veinna, Austria. I participated in three International Workshops held at ICARDA and one workshop and two "Chickpea Scientists Meet" at ICRISAT. In 1983, I obtained an award from International Development Research Centre (IDRC), Canada for my Ph.D studies at Andhra Pradesh Agricultural University (APAU) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). I worked on chickpea breeding methodology under the guidance of my Advisory committee for my PhD thesis.