GENETIC STUDIES ON FLOWER COLOUR, PROTEIN CONTENT AND SOME IMPORTANT QUALITATIVE AND QUANTITATIVE CHARACTERS IN TWO CROSSES OF CHICKPEA

(*Cicer arietinum* L.)

By
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CERTIFICATE

Ms **N. V. SATYA VIJAYALAKSHMI** has satisfactorily prosecuted the course of research and that the thesis entitled, **GENETIC STUDIES ON FLOWER COLOUR, PROTEIN CONTENT AND SOME IMPORTANT QUALITATIVE AND QUANTITATIVE CHARACTERS IN TWO CROSSES OF CHICKPEA (*Cicer arietinum* L.)** 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 her for a degree in any University.

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Co-Advisor

(Dr. T. NAGESHWAR RAO)
Major Advisor

Date : 8/12/99
Place : Hyderabad

CERTIFICATE

This is to certify that the thesis entitled "**GENETIC STUDIES ON FLOWER COLOUR, PROTEIN CONTENT AND SOME IMPORTANT QUALITATIVE AND QUANTITATIVE CHARACTERS IN TWO CROSSES OF CHICKPEA (*Cicer arietinum* L.)**", submitted in partial fulfillment of the requirements of the degree of `MASTER OF SCIENCE IN AGRICULTURE' of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of bonafied research work carried out by Ms. **N. V. SATYA VIJAYALAKSHMI** under our 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 by the student for any other degree or diploma. All assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.

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ABSTRACT

Studies were carried out to investigate the genetics of flower colour, seed protein content, crude fibre content and qualitative and quantitative characters in two crosses of chickpea (*Cicer arietinum* L.) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P., during the *Rabi* season 1997/98.

The material for the present investigation comprised of three parents P 9623, RS 11 and T 39-1, and F_1 and F_2 generations of two crosses P 9623 x T 39-1 and RS 11 x T 39-1. P 9623 and RS 11 are white flowered, moderate and low protein lines used as female parents, while T 39-1 is a blue flowered, high protein line used as a common male parent. The seeds of the parental, F_1 and F_2 generations were sown in an unreplicated block with a spacing of 60 x 20 cm on 14 October 1997. The crop was grown rainfed and normal cultural operations and plant protection measures were taken up to grow a healthy crop. The following results were obtained from these studies:

- Inheritance studies on flower colour showed the presence of three different genes governing flower colour. Supplementary type of gene action was observed in the two crosses. The genotypes for white flower colour for P 9623 and RS 11 were different. The

three genes are probably the same as C, B and P, reported in the literature earlier. Therefore, the genetic constitution of the three parents and two F_1s are:

P 9623 - CCbbPP (White) F_1 (P 9623 x T 39-1) - CCBbPp (Pink)
RS 11 - ccBBPP (White) F_1 (RS 11 x T 39-1) - CcBBPp (Pink)
T 39-1 - CCBBpp (Blue)

These accessions should be useful for conducting allelic tests for determining flower colour alleles in future genetic studies.

- In both the crosses seed protein content appeared to be governed by several genes. This is based on the near normal frequency distribution in F_2 generations of both the crosses. Low protein showed dominance over high protein content. High crude fibre showed dominance over low fibre content. The frequency distribution for each F_2 was near normal suggesting multigenic control for this character also. Transgressive segregation was observed towards high fibre content in both the crosses indicating the presence of genes for high fibre content in the low parents as well.

- Positive correlations of seed yield with number of pods and seeds per plant were obtained in both the crosses. Number of primary and secondary branches per plant, and seeds per pod also influenced seed yield either directly or indirectly through number of pods and seeds. Seed protein and crude fibre content were negatively correlated with 100-seed weight in the cross P 9623 x T 39-1, while they were negatively correlated with each other in the cross RS 11 x T 39-1. These traits were largely unrelated to other traits including seed yield suggesting that simultaneous selection for improving these characters is possible without affecting yield.

- P 9623 has larger kabuli seeds, RS 11 has high seed yield and high fibre content, while T 39-1 has high seed protein content. These could be combined and selected for in segregants derived from their crosses.

- The cross P 9623 x T 39-1 was found better for developing high yielding segregants with high protein and low fibre content, useful for nutrition and *dhal* recovery purposes. It also produced larger seeded kabuli type segregants. RS 11 x T 39-1 appeared more suitable for developing high yielding genotypes with high fibre content. The latter trait is known to offer resistance to root diseases and bruchids.

- Heterosis was observed for seed yield in both the crosses. It appeared to be due to the cumulative effect of heterosis for number of primary and secondary branches, pods and seeds per plant, and seeds per pod.

- Linkage was observed between blue flower colour, high protein content and small seed size. Thus simultaneous improvement for protein content and seed size may require careful selection. Desi type segregants with low fibre content were obtained. This has implications for increased *dhal* recovery.

- In the present study, the cross P 9623 x T 39-1 appeared superior because of bolder seeds, high protein and low fibre content, and good seed yield. Therefore, superior segregants can be expected from this cross.

DECLARATION

I, **N. V. SATYA VIJAYALAKSHMI** hereby declare that the thesis entitled **"GENETIC STUDIES ON FLOWER COLOUR, PROTEIN CONTENT AND SOME IMPORTANT QUALITATIVE AND QUANTITATIVE CHARACTERS IN TWO CROSSES OF CHICKPEA (*Cicer arietinum* L.)"**, submitted to Acharya N.G. Ranga Agricultural University for the Degree of **MASTER OF SCIENCE IN AGRICULTURE** is a result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Vijayalakshmi N.V.S

(N. V. SATYA VIJAYALAKSHMI)

Date : 3/12/99
Place : Hyderabad

Abbreviations

1.	Centimetre	cm
2.	Chi-square	χ^2
3.	Degree centigrade	°C
4.	Gram	g
5.	Hectare	ha
6.	Hour	hr
7.	Kilogram	kg
8.	Metre	m
9.	Milligram	mg
10.	Millilitre	ml
11.	Millimetre	mm
12.	Minutes	min
13.	Normality	N
14.	Parts per million	ppm
15.	Percentage	%
16.	Standard error	S.E.

INTRODUCTION

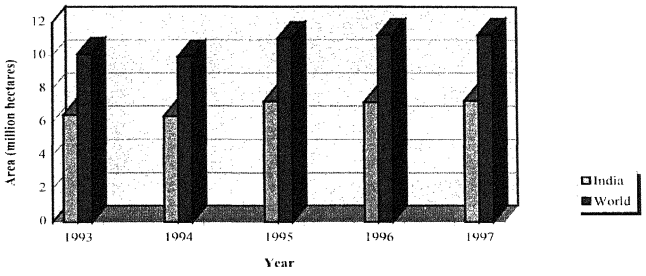
CHAPTER I

INTRODUCTION

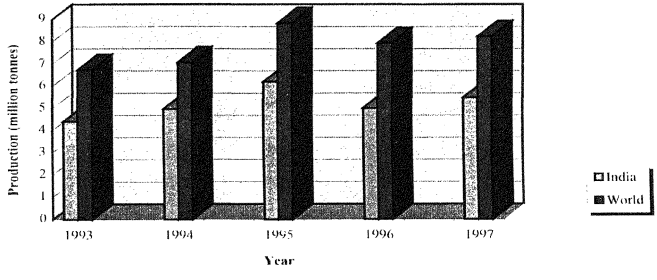
Food legumes can be defined as the plants belonging to the family Papilionaceae which are used as food in the form of unripe pods and green grains or dry seeds directly or indirectly. The family Papilionaceae is the second most important family next to Graminae, as a source of food and fodder. Pulses or food legumes have been traditionally recognized as an indispensable constituent of the Indian diet. They supplement the cereal rich diet of predominantly vegetarian masses by virtue of their being rich in protein and several essential amino acids especially lysine and hence referred to as "Poor man's meat" and "rich man's vegetable". They also provide nutritious fodder to the cattle.

These crops commonly referred to as "mini fertilizer factories" are unique in the sense that they have a built-in mechanism to fix atmospheric nitrogen through symbiosis with *Rhizobium* spp.. They can utilize soil moisture efficiently because of their long roots and have a capacity of yielding something even under marginal and most neglected conditions with low inputs. They also improve soil physical structure, fit well in mixed or inter cropping systems, crop rotations and dry farming.

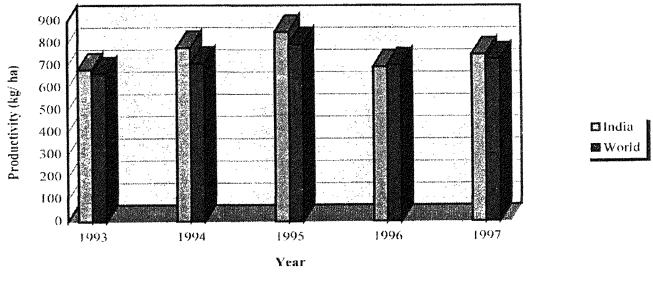
India is a major pulse growing country in the world sharing 37% area and 25% production for these crops (FAO, 1998). Chickpea (*Cicer arietinum* L.) also known as bengal gram, gram, chana and garbanzo bean, ranks as the third most important pulse crop in the world after beans (*Phaseolus vulgaris* L.) and peas (*Pisum sativum* L.). It is the



Area



Production



Productivity

Figure 1 : Area, production and productivity of chickpea in India and World.
(*Source* : FAO Bulletins).

premier pulse crop of India accounting for 28% of total pulse crops area and 38% of their production (FAO, 1998). It is grown on an area of about 7.3 million hectares with a production of approximately 5.5 million tonnes and productivity of 753 kg/ha (FAO, 1998).

National Commission on Agriculture projected a production of 24.7 million tonnes of pulses to meet the protein requirement of the country by 2000 AD. In comparison the production in 1997 was only 15.0 million tonnes (approximately). It is therefore, necessary to increase the productivity substantially. It will be desirable that quality of pulses is also considered in addition to their yield traits.

Protein is the basis of life. Today crops and foods are evaluated for their calories, protein, vitamin and other contents. Pulses contain two to three times as much protein as cereals and form an important source of protein in the Indian diet. But the potentiality of the pulses has not been fully exploited as a source of protein in human diets.

Chickpea has a crude protein in the seed in the range of 12.6%-30.5% (Singh, 1985). The development of high protein varieties can help to alleviate the protein deficiency, which now exists. This therefore, underlines the importance of breeding for high protein content in chickpea.

Linkage between flower colour, protein content and seed size has been reported (Kumar *et al.*, 1982). The blue flower colour, high protein content and small seed size were linked. But the linkage was not tight. To recover segregating plants combining high seed

protein percentage with large seeds, genetic studies on flower colour and seed protein content become important.

Two types of chickpea are recognized namely desi and kabuli types. The former is generally yellow to brown coloured with small angular seeds, while the latter is cream coloured with large owl's head shaped seeds. These also usually differ in their fibre content, which is mainly deposited in the seed coat (Singh *et al.*, 1980). The proportion of seed coat or fibre content plays an important role in the nutritive value and processing of chickpea. Lesser seed coat or fibre content raises the theoretical maximum recovery of *dhal* and increases the energy available to monogastric animals. Therefore, the study of inheritance of crude fibre content is important.

The progress in breeding of any crop depends on the efficiency of the selection criteria. Suitable selection criteria in a segregating population depend upon the nature and magnitude of association between characters. Correlation is an important statistical technique for identifying useful characters influencing yield and undesirable association between the component characters. This emphasizes the importance of correlation studies.

Crop improvement depends upon the magnitude of genetic variability present in base population. More diverse the parents, within limits of fitness, the greater are the chances of obtaining higher amount of heterotic expression in hybrids and broad spectrum of variability in segregating generations. The scope for exploitation of hybrid vigour will

depend on the direction and magnitude of heterosis. Exploitation of heterosis appears to be one of the methods for increasing the yield in many crops including chickpea.

Considerable work is required to study the genetics of flower colour, seed protein content, crude fibre content and yield and yield contributing characters in chickpea. Therefore, the present investigation was carried out with the following objectives:

1. To study the inheritance of flower colour in two crosses involving parents with different flower colours.
2. To study the inheritance of seed protein and crude fibre content in these crosses.
3. To study the correlations between yield, yield contributing characters, seed protein and crude fibre content in these crosses.
4. To study the differences among the parents and their crosses for various qualitative and quantitative characters.
5. To measure the extent of heterosis for different traits in these crosses.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Review of literature pertaining to inheritance of flower colour, seed protein content, crude fibre content, correlations, variability for yield and yield components and heterosis in chickpea is presented briefly under the following headings:

2.1 Inheritance of flower colour

2.2 Inheritance of seed protein content

2.3 Inheritance of crude fibre content

2.4 Correlation coefficients

2.5 Variability for characters

2.6 Heterosis

2.1 Inheritance of flower colour

In chickpea, there are three distinct flower colours namely pink, blue and white. Flower colour has profound effect on seed coat colour. Usually white flowered plants produce light coloured seed. But in some cultivars like RS 11, there are exceptions where white flowered plants give dark coloured seed. Two white flowered varieties when crossed produced pink flowers indicating the presence of different genes controlling their flower colour (Kumar, 1997). Therefore, the study of flower colour inheritance in chickpea is

important in crosses involving such parents. A review of literature for flower colour inheritance in chickpea is presented hereunder.

Khan and Akhtar (1934) studied genetics of flower colour in F_1 and F_2 generations of several crosses involving blue, pink and white flowered chickpea types and reported that blue colour was due to a single factor B; a factor P gave pink colour in the presence of B but was itself without colour effect and a green colour of the standard petal was obtained in the absence of a factor W. They obtained a ratio of 9 pink : 3 blue : 4 white colours in crosses involving white and blue types, and a 3 : 1 ratio of pink with both blue and white, pink being dominant to either. Later Pal (1934) obtained similar results based on a series of crosses and confirmed that flower colour depends upon the interaction of two gene pairs.

Ayyar and Balasubramanian (1936) found that the inheritance of flower colours, pink, blue and white was governed by three factors, two complementary factors C and B which together produced blue and a factor P which converted blue into pink. In the absence of C or B, the flowers were white.

Kadam *et al.* (1941) crossed a type of gram having salmon coloured petals with a type having pink petals and obtained a pink F_1. In F_2, they observed a ratio of 3 pink : 1 salmon. On crossing with a white flowered type, they got a pink F_1 and a ratio of 9 pink : 3 salmon : 4 white in F_2. They designated the gene producing salmon colour as Sa. Later they crossed a type having high purplish petals with a white flowered type and

observed a purple F_1 and a 3 : 1 ratio of pink and white in F_2. They designated the gene producing purple veined flowers as Pu.

Pimplikar (1943), Khan *et al.* (1950), Patil (1964) and Athwal and Brar (1967) studied crosses between white and pink flowered strains, and observed that the pink was dominant to white flower colour being monogenically governed. They obtained pink and white flower segregation in the ratio of 3 : 1. Athwal and Brar (1967) designated the gene pair governing flower colour as Pp.

Bhapkar and Patil (1963), Patil (1967) and Nayeem *et al.* (1977) showed from the crosses between blue and pink flowered mutants that flower colour was monogenically controlled, with pink being dominant to blue. Bhapkar and Patil (1963) observed that flower colour and seed coat colour were linked with a linkage value of about 18%. Nayeem *et al.* (1977) designated the gene governing corolla colour as Pkco.

D'Cruz and Tendulkar (1970) showed from F_1 and F_2 generations of the cross Double pod x White flower White gram that three genes Pco_a, Pco_{b1} and Pco_{b2} governed corolla colour and were pleiotropic in controlling stem and corolla colour. They detected linkage between corolla colour, number of flowers per axil, testa colour and seed shape.

More and D'Cruz (1970) obtained F_2 segregation ratio of 9 pink : 3 blue : 3 salmon pink : 1 white for corolla colour and controlled by two genes, Sco and Bco acting independent of each other.

Khosh-Khui and Niknejad (1971) and Mian (1971) studied F_1, F_2 and F_3 generations of reciprocal crosses between white and purple flowers and observed monogenic inheritance for flower colour, purple being dominant over white, with no maternal effects.

Deshmukh *et al.* (1972) and Pawar and Patil (1979) suggested that two genes, designated Lvco and Wco governed corolla colour giving a ratio of 9 : 3 : 4. Lvco produced violet when present alone and pink in association with Wco, but Wco had no visible effect by itself and white corolla resulted from the absence of Lvco.

Jagtap *et al.* (1973) studied the crosses between the *Cicer arietinum* mutants Pusa 83 D. P., Green bold and the selection P 4-14-1 (triangular cross) and found that corolla colour was controlled by one gene Pco. Genes for corolla colour, testa colour, midrib colour, seed surface and leaflet size formed a single linkage group called Pco linkage group.

Patil and Deshmukh (1975) found the corolla colour to segregate in 9 : 3 : 3 : 1 ratio and governed by two genes Bco and Sco in a cross T-54-A x D-70-10.

More and D'Cruz (1976) studied the cross NP 6 x Pusa 83 D. P. and found that corolla colour was controlled by single gene Pco. Phadnis (1976) conducted inheritance studies on F_2 and F_3 generations of crosses between lines having white or pink flowers in

Cicer arietinum. He noted that A was a dominant gene for pink flowers; B and C each singly resulted in white flowers but were complementary, resulting in pink flowers when both were present; one of the complementary genes inhibited A.

Reddy and Chopde (1977) worked on two crosses in *Cicer arietinum*. In a cross between violet flowered Chikodi V.V. and pink flowered *Chrysanthefolia* type, two complementary genes, designated Pco_a and Pco_b conditioned flower colour, pink being dominant. In another cross between violet flowered Chikodi V.V. and white flowered type Kh. 908-21, they observed that a single dominant gene Lvco governed flower colour, violet being dominant.

Reddy and Nayeem (1978) observed in a cross between pink flowered D-70-10 and White flower White grained mutant that pink corolla colour was governed by a single dominant gene Pco. Pleiotropic action of Pco effected the traits like petal-vein, stem, pedicel and testa colour, and seed shape. Yadav *et al.* (1978) had also obtained similar results in a cross between pink and white flower types.

Rao *et al.* (1980) studied the inheritance of light blue corolla in F_1, F_2 and backcross generations of seven crosses involving blue and pink flowered types. They obtained pink F_1s and F_2 segregation ratio of 9 pink : 3 light pink : 3 blue : 1 light blue. They showed that light-blue corolla involved interaction of two recessive alleles.

Kumar *et al.* (1982) studied F_2 segregation ratio of the cross T-1-A x Annigeri and indicated that flower colour was monogenically inherited, with pink being dominant. Blue flowered plants had higher seed protein content and smaller seeds than pink flowered plants indicating linkage between the genes governing the three characters. Linkage was not tight, hence they concluded that segregating plants combining a high seed protein percentage with large seeds might be recoverable from large populations.

Pawar and Patil (1982 and 1983) found in the cross, Chikodi V.V. x D-70-10 that single gene Pco controlled corolla colour, with pink dominant to light violet. The factors for corolla colour, seed coat colour and seed surface formed one linkage group

Kidambi *et al.* (1988) studied parents, F_1, F_2, BC_1 and BC_2 generations of a cross between white and purple flower types. Flower colour segregation in F_2 and BC_1 indicated that purple was monogenically dominant over white colour.

Singh *et al.* (1988) worked out the association among Fusarium wilt resistance, flower colour and number of flowers per fruiting node in crosses made between genotypes differing for the above characters in chickpea. They observed that F_1s had pink flowers and the ratio of pink to white flowered plants in F_2 was consistent with segregation of a single locus, with pink dominant over white. They observed that flower colour was inherited independently of flower number and wilt reaction.

Davis (1991) investigated the linkage relationship of genes for leaf morphology, flower colour and root nodulation in crosses between purple and white flowered lines, and among white flowered lines. He demonstrated that the two white flowered lines carried non-allelic, single recessive genes for white flower colour, provisionally designated w_1 and w_2 respectively. He showed that the gene for filiform leaf trait fil and w_2 were linked.

Gil and Cubero (1993) studied the relationship of seed coat thickness to seed size and flower colour in the crosses between pink flowered desi and white flowered kabuli types and obtained the expected ratio of 3 pink : 1 white with pink dominant over white. Linkage was found between seed coat thickness and flower colour, the recombinant fraction being 0.19.

Kumar (1997) reported complementation for pink flower colour in two crosses of white flowered chickpea accessions. In the cross P 9623 x RS 11, F_1 was pink and in F_2 flower colour segregated in the ratio of 9 pink : 7 white showing complementary type of gene action.

Pundir and Reddy (1997) presumed that non-anthocyanin stem and white flower, and low anthocyanin stem and coloured flower were governed by two different alleles of the same gene as they could not recover the trait combination of low anthocyanin stem and white flower in the segregating progenies of crosses between desi and kabuli types.

From the above studies, the inheritance of flower colour is reported to be monogenic, digenic and trigenic. Thus, at least three genes are governing the flower colour in chickpea.

Trigenic inheritance model was proposed by Ayyar and Balasubramanian (1936), D'Cruz and Tendulkar (1970) and Phadnis (1976). The gene symbols C, B and P given by Ayyar and Balasubramanian (1936) and Pco_a, Pco_{b1} and Pco_{b2} given by D'Cruz and Tendulkar (1970) could be same, as no allelic tests have been conducted.

Digenic inheritance model was proposed by Khan and Akhtar (1934), Pal (1934), Kadam *et al.* (1941), More and D'Cruz (1970), Deshmukh *et al.* (1972), Patil and Deshmukh (1975), Reddy and Chopde (1977), Pawar and Patil (1979), Rao *et al.* (1980) Davis (1991) and Kumar (1997). The different gene designations given by these workers namely B and P, Bco and Sco, Lvco and Wco, and Pco_a and Pco_b could be same.

All other workers have proposed monogenic inheritance model. The gene symbols used by them namely P, Pco, Pkco and Lvco could be probably the same. Thus, the segregation for one, two or three gene pairs will depend on the genetic constitution of the parents. Some workers reported that genes for corolla colour had pleiotropic effect on seed coat colour and seed shape while some others reported linkage between genes for flower colour, seed coat colour and seed shape.

2.2 Inheritance of seed protein content

Chickpea is one of the important pulse crops from nutritional point of view as it has high net protein and vitamin content. The genetic improvement of seed protein content has not been impressive. Improvement in seed protein content requires consideration of its inheritance pattern. A review of literature on inheritance of protein content is presented in this section.

Sandhu *et al.* (1968) found significant reciprocal effects for percentage seed protein from the study on 33 genotypes of chickpea. Sandhu *et al.* (1974) assayed seeds of 33 genotypes of chickpea for total protein and evaluated for morphological, agronomic and protein characters. The study revealed that protein percent ranged from 14.5 to 28.9 with a mean of 21.8, a highly significant negative phenotypic correlation (r =-0.57) between protein percent and 100-seed weight, and highly significant year and genotype interaction for protein percent.

Tyagi *et al.* (1982) found a range of 18.4 - 29.1% for seed protein content in 45 chickpea cultivars. They observed in F_1 of three reciprocal crosses involving five of these lines that seed protein content was primarily determined by maternal genotype and in F_2 reciprocal differences were small and non-significant without any cytoplasmic basis for these differences.

Garcia *et al.* (1985) studied four crosses to observe the segregation pattern for protein content in F_2 and F_3 generations and reported that genetic system for protein

content was heterogeneous with no similarity in the patterns of segregation among the four crosses.

Rang *et al.* (1986) from the data on seven generations of two chickpea crosses indicated duplicate type of gene interaction for protein content and the presence of linkage and/or multigenic interactions for this trait. They suggested biparental mating to recover desirable recombinants in the segregating populations of these crosses.

Tyagi and Singh (1988) had taken significant reciprocal differences for protein content of F_1 seeds from a 5x5 diallel and their absence in F_2 to show the importance of the maternal genotype and found that the differences did not have a cytoplasmic or extra chromosomal basis.

Singh *et al.* (1990) reported that yield and protein content followed normal distribution pattern. They identified some kabuli chickpea lines, which maintained high protein content with low variability when grown for two seasons over two different growing locations.

Singh *et al.* (1992) worked on yield and yield traits including protein content in the parents, F_1 and F_2 of a 10 x 10 diallel and desi cultivars wherein graphic analysis showed over dominance and partial dominance for protein content.

Till date studies have revealed that protein content is governed by multigenes with much effect of environment on this character. Genotype x environment interaction is found significant (Krober, 1970; Dahiya *et al.*, 1982 and Sengupta *et al.*, 1986) with location effecting this character more than growing season (Singh *et al.*, 1983). However, some reports indicated high heritability (Sandhu *et al.*, 1989) for this character suggesting that selection after hybridization could result in its improvement.

2.3 Inheritance of crude fibre content

Desi and kabuli chickpea differ in their fibre content, 80% of which is mainly deposited in the seed coat (Singh, 1984). Anti nutritional factors such as phenols have been reported to be concentrated in the seed coat. The proportion of seed coat plays an important role in the nutritive value and processing of chickpea. The proportion of seed coat or seed fibre affects the recovery of *dhal*, the major form of chickpea consumption. Inheritance study of crude fibre content may help breeders understand this character better and develop varieties with low crude fibre content. A review of literature on inheritance of crude fibre content is presented below.

Singh *et al.* (1980) reported wide variation for seed coat percentage and seed coat thickness among desi and kabuli cultivars. They indicated that it may not be possible to reduce the thickness of seed coat by selecting for increased seed weight, although the proportion of seed coat is lower in large seeded than small seeded types.

Singh (1984) observed that desi and kabuli chickpeas could be characterised by the seed fibre content and seed coat thickness. Desi types always had a higher fibre content and a thicker seed coat.

Kumar and Singh (1989) reported large variation for seed coat percentage and seed coat thickness among 40 cultivars of chickpea, and even greater between the two main types, desi and kabuli. In a cross between the two types, 3% individuals were parental types and rest were non parental types which indicated that several genes governed this trait and the genes for thick seed coat were partially dominant (DD + 0.5) over those for thin seed coat. They also indicated the possibility of development of desi cultivars with thin seed coat.

Kharrat *et al.* (1990) observed that desi seeds were characterised by a higher fibre content and a small seed size than the kabuli ones. However, there was no genetic correlation between fibre content and seed size in both groups but only association which was generated by human selection for large sized grains with thinner seed coats because of the importance of these characters in human nutrition in Mediterranean and Middle East countries. Heritability estimate was high for fibre content (H = 0.88). They suggested a fairly high response to the selection for both fibre content and seed size in a breeding programme.

Gil and Cubero (1993) found that seed fibre content or seed coat thickness exhibited monogenic inheritance, the thin kabuli seed coat being the recessive character. They found no relationship between seed coat thickness and seed size.

Fibre content is more in desi types compared to kabuli types. It showed no relationship with seed size. Studies on inheritance pattern of this revealed both monogenic and polygenic control.

2.4 Correlation coefficients

Correlation coefficient is an important statistical tool for determining association between two characters. Strong association or its absence between any two traits influences selection for combination of these characteristics.

Seed yield is a complex character. For augmenting yield, the role of component characters is well appreciated. Understanding of the inter-relationship between seed yield and its components and among the components themselves is necessary to improve seed yield. A review of literature for correlations of yield with yield contributing traits and among the traits including seed protein and crude fibre content is presented hereunder.

Singh *et al.* (1980) studied seed coat content of desi and kabuli chickpea cultivars and found a significant negative correlation between seed coat percentage and seed weight. They also found that seed coat thickness was highly correlated with seed coat content but non-significantly correlated with seed weight.

Association studies were carried out in chickpea genotypes by Salimath and Bahl (1986), Mishra *et al.* (1988), Singh *et al.* (1989) and Chavan *et al.* (1994) who reported significant positive association of seed yield with number of primary branches per plant, secondary branches per plant and pods per plant, and suggested selection for these characters to improve yield.

Paliwal *et al.* (1987) observed in 36 genotypes of chickpea that seed yield per plant was positively correlated with plant height (r=0.47) and further recommended pods per plant and seeds per pod as selection criteria to improve seed yield.

Sindhu and Prasad (1987) and Malik *et al.* (1988) observed that 100-seed weight, pods per plant and seeds per pod were positively correlated with seed yield in chickpea lines. Choudhury and Mian (1988) studied 13 genetically divergent chickpea lines and observed positive and significant association between number of secondary branches and plant height, seed yield and pods per plant, and seed yield and 1000-seed weight. Their results indicated that selection would be effective for primary branches per plant, pods per plant and 1000-seed weight.

Seed yield was positively correlated with number of branches per plant i.e. primary and secondary branches, pods per plant and 100-seed weight. This was reported by Jivani and Yadavendra (1988), Sharma and Maloo (1988), Uddin *et al.* (1990), Rao

et al. (1994) and Tripathi *et al.* (1995) by working on chickpea cultivars. They suggested that these characters could be taken as selection criteria for seed yield improvement.

Reddy and Rao (1988) analysed 50 F_2 populations derived from intervarietal crosses and reported that seed and pod number per plant were positively associated with yield per plant. Plant height had significant positive association with 100-seed weight. Number of pods per plant was positively associated with number of seeds per plant. Plant height and 100-seed weight showed non-significant positive association with yield.

Sandhu *et al.* (1988) studied 129 diverse strains of *Cicer arietinum* and reported that seed yield per plant was positively and significantly associated with number of pods per plant, secondary branches per plant, primary branches per plant and seeds per pod and suggested selection for secondary branches per plant and seeds per pod to improve seed yield. Shukla (1988) studied correlations between seven quantitative traits in 685 chickpea accessions and reported significant and positive phenotypic correlations between yield and plant height (r=0.22), total branches (r=0.35), pods per plant (r=0.61) and seeds per pod (r=0.32).

Waldia *et al.* (1988) observed in F_2 of three crosses that there was an optimum range of seed mass for each cross where the association between seed mass and seed yield was high and positive. They suggested that in selecting genotypes for higher seed mass, a balance should be struck to avoid reduction in yield.

Sadhu and Mandal (1989) observed in 48 diverse chickpea lines that seed yield was positively correlated with primary and secondary branches per plant, pod number and seed number per plant. Seed weight was negatively correlated with seed number and seeds per pod. Sandhu *et al.* (1989) evaluated 123 genotypes and found grain yield to be positively correlated with pods per plant, seeds per pod and secondary branches, and grain protein to be negatively correlated with pods per plant. Protein content was largely unrelated to the other characters.

Ali (1990) conducted studies on six advanced lines of desi chickpea, compared with two check cultivars and found positive association of grain yield with plant height and grain mass. He suggested to consider longer duration to flowering, late maturity and large grain mass while selecting genotypes for grain yield.

Kharrat *et al.* (1990) in their study on a cross of a desi and a kabuli line observed no correlations between protein content and seed size, protein and fibre content, and seed size and fibre content. Singh *et al.* (1990) also observed non-significant correlation coefficient between protein content and 100-seed weight while studying some kabuli chickpea lines.

Tagore and Singh (1990) studied 200 *Cicer arietinum* germplasm accessions under normal and increased input conditions. They found that grain yield was positively and significantly associated with number of primary branches per plant, pods per plant, seeds per pod and 100-seed weight under increased input condition. They reported

stronger correlation of yield per plant with number of primary branches, seeds per pod and 100-seed weight under increased input condition than under normal condition.

Yadav (1990) conducted studies on F_2 population of three chickpea crosses which indicated that seed yield was significantly and positively correlated with number of seeds per plant, number of pods per plant, number of secondary branches, 100-seed weight and plant height.

Bejiga *et al.* (1991) studied F_2-F_6 generations of nine crosses of chickpea and observed in all generations that seed yield per plant was positively and significantly correlated with number of primary and secondary branches, number of pods and seeds per plant and 20-seed weight. They also observed significant positive correlations between number of pods per plant and seeds per plant, and between number of secondary branches and number of pods and seeds per plant. They suggested simultaneous selection of secondary branches, pods and seeds per plant to increase yield.

Chhina *et al.* (1991) evaluated 14 cultivars of *Cicer arietinum* under rainfed conditions and obtained high positive correlations of seed yield with pods per plant and number of secondary branches. Pods per plant was also significantly correlated with secondary branches. They suggested consideration of pods per plant and number of secondary branches in breeding high yielding varieties suitable for rainfed conditions.

Eser *et al.* (1991) studied three varieties, which were calibrated according to seed size into large, medium and small types. They concluded that the highest values of yield and yield components were obtained from large seeds indicating the positive influence of seed mass on yield and its components.

Jahhar and Mane (1991) found grain yield to be significantly correlated with all yield components except plant height in variety PG 5 (Vishwas) of gram. Kharrat *et al.* (1991) crossed local Spanish cultivars of the kabuli type with two ICRISAT lines (one desi and one kabuli) and found that seed yield per plant was significantly and positively correlated with pods per plant, seeds per plant and seed size. There was no correlation of seed size with seeds per plant. They suggested the use of desi-kabuli introgression for the improvement of seed yield.

Pundir *et al.* (1991) found that leaf and leaflet area, and 100-seed weight were positively correlated with each other but negatively correlated with seed protein content in 25 *Cicer arietinum* accessions. They also found negative correlation between 100-seed weight and seeds per pod. Sandhu *et al.* (1991) in two different studies on genetically diverse lines of chickpea for yield related characters and protein content found that seed yield was positively associated with seeds per pod, primary and secondary branches and pods per plant and latter three traits were correlated among themselves. Protein content had no significant association with any one of these.

Abdali (1992) worked out correlations on F_4 and F_5 generations of three chickpea crosses which revealed that grain yield expressed highly significant positive association with number of pods (0.78-0.94), number of seeds (0.79-0.93) and secondary branches (0.51-0.87) in all crosses at two generations. Number of pods per plant was significantly and positively correlated with number of seeds per plant and secondary branches in three crosses in both generations.

Akdag and Sehirali (1992) found significant positive correlations between seed yield per unit area and protein yield per unit area, and between seed yield per plant and plant height, number of primary branches, pods and seeds per plant. They reported significant negative correlation between seed yield per plant and plant density.

Bouslama *et al.* (1992) and Varghese *et al.* (1993) reported significant positive association of seed yield with pods per plant and 100-seed weight, and considered these traits as important yield components in selection of better genotypes in chickpea. Dasgupta *et al.* (1992) observed significant and positive correlations of seed yield with pods per plant, seeds per plant and 100-seed weight. They observed significant positive correlations between seeds per plant and seeds per pod, and between pods per plant and seeds per plant in 28 genotypes of chickpea. They observed significant negative correlation between seeds per pod and 100-seed weight.

Jadhav *et al.* (1992) studied yield correlations of irrigated *Cicer arietinum* and safflower under various intercropping combinations. They found the number of

productive pods per plant and seeds per plant to be most highly correlated with seed yield per plant, followed by number of total pods per plant, 1000-seed weight and number of branches per plant in *Cicer arietinum*. Chavan *et al.* (1993) in a field study on 11 chickpea cultivars grown under rainfed and irrigated conditions found significant positive correlation between seed yield and protein content and observed that irrigation significantly increased seed yield and protein content.

Lal *et al.* (1993) reported in chickpea genotypes that seed yield was positively and significantly correlated with pod number and plant height, and negatively correlated with 100-seed weight. Plant height showed significant negative correlation with branch number. Pod number had significant negative correlation with 100-seed weight. They suggested pod number and plant height as important characters for seed yield.

Sathe *et al.* (1993) studied six cultivars of chickpea and noted significant and positive correlations of grain yield with number of grains per plant, 100-seed weight and number of filled pods per plant. Correlations were significant and positive between plant height and 100-seed weight, number of branches and total number of pods per plant, number of filled pods and number of grains per plant and 100-seed weight, and number of grains per plant and number of seeds per pod. Negative correlation was found between 100-seed weight and number of seeds per pod.

Arora and Kumar (1994) evaluated forty *Cicer arietinum* genotypes and observed that seed yield per plant was positively associated with pods per plant, plant height and

100-seed weight. Bhambota *et al.* (1994) worked out correlation coefficients of 32 genotypes at two sowing dates in two years. They reported positive association of pod bearing branches per plant, pods per plant and plant height with seed yield in all four environments individually as well as pooled over environments. They suggested the selection for more pods per plant in the production of high yielding genotypes. Sarvaliya and Goyal (1994) observed significant association between yield and 100-seed weight, plant height, number of primary branches per plant and number of pods per plant in 76 chickpea genotypes.

Singh and Rheenen (1994) crossed JG 62 and MS 24, evaluated them along with their F_1s, F_2s and backcross progenies, and observed that seeds per pod was positively correlated with seed yield in segregating generations ($r = 0.18$). Deshmukh and Patil (1995) revealed that grain yield was positively correlated with pods per plant and harvest index in chickpea varieties and their F_1 hybrids.

Khorgade *et al.* (1995) showed significant positive association of seed yield with pods per plant, branches per plant and 100-seed weight, whereas seeds per pod had significant negative association with seed yield per plant under normal and late sown conditions in 30 genotypes of chickpea. Sandhu and Mangat (1995) studied eight characters in 32 diverse genotypes of chickpea and showed that yield per plant was significantly and positively associated with primary branches and pods per plant, and negatively associated with plant height (45 days after sowing).

Singh *et al.* (1995) studied 15 *Cicer arietinum* F_2 and F_3 generations and reported that seed yield per plant had a significant positive correlation with pods per plant in both generations.

Mathur and Mathur (1996) showed significant positive correlations of grain yield per plant with pods per plant and 1000-grain weight, but negative correlation with plant height in 34 chickpea varieties. Ozdemir (1996) showed that the relationship between seed yield and number of pods per plant was significant and positive. Chand and Singh (1997) observed that number of pods and seeds per plant were the most important yield contributing characters in chickpea genotypes. Manjare *et al.* (1997) reported on 22 genotypes of chickpea that grain yield per plant had positive correlations with number of pods per plant, number of branches per plant, 100-seed weight and number of grains per pod. However, only number of pods per plant exhibited significant correlation.

Over all, number of pods per plant, number of seeds per plant, number of primary and secondary branches showed positive correlations with seed yield. Correlations of seed yield with plant height, 100-seed weight and seeds per pod were positive in some studies while negative in other studies. Protein and fibre content were largely unrelated to other characters. In some cases, negative correlations of protein content with number of pods per plant and 100-seed weight were observed. However, in some studies protein content was positively correlated with seed yield.

2.5 Variability for characters

Variability is the genetic basis for crop improvement. Success of any plant improvement programme lies in careful management of this variability. Inclusion of genetically divergent parents in crop breeding helps to create new reservoirs of genetic variability and recombination of genes from diverse sources. Chickpea is a self pollinated crop and requires extensive studies to exploit the existing variability and utilise it in various breeding programmes to improve yield, protein content and other desirable characters. A review of literature on variability in chickpea follows.

Choudhury and Mian (1988) and Sandhu *et al.* (1988) reported that chickpea lines they studied showed existence of significant variation for yield and related characters.

El-Shatnawi (1988) observed continuous variation with transgressive segregation at F_2 generation for most of the traits studied except for 100-seed weight and plant height. Kidambi *et al.* (1988) in a study of three crosses, each having seven generations, P_1, P_2, F_1, F_2, F_3, BC_1 and BC_2 observed genetic differences for all crosses and for all traits studied namely plant height, number of primary branches and number of secondary branches per plant.

Kumar and Singh (1989) studied 40 cultivars of chickpea (*Cicer arietinum* L.) belonging to two main types. desi and kabuli and observed a large variation for 100-seed

weight (11.3 - 43.9 g) and seed coat thickness (36.5 - 205.0 μm) within and between the two types.

Sadhu and Mandal (1989), Samal and Jagdev (1989), Sharma *et al.* (1990), Pundir *et al.* (1991) and Sandhu *et al.* (1991) observed significant differences for plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, 100-seed weight and seed yield per plant in chickpea genotypes. Variability in protein content was also observed among chickpea genotypes by Sharma *et al.* (1990), Pundir *et al.* (1991) and Chavan *et al.* (1993). Singh and Singh (1989) noted greatest genotypic variability in 100-seed weight, pods per plant and seed yield per plant indicating scope for improvement by selection for these traits in 66 genotypes of chickpea.

Kharrat *et al.* (1990) in a cross between a desi and a kabuli line found the ranges of variation for protein content within kabuli from 20.6 - 27.3% and within desi from 19.9 - 26.8%. They observed variation for fibre content also. Desi seeds were characterised by a higher fibre content and a smaller seed size compared to kabuli seeds.

Shinde and Deshmukh (1990) found a wide variation in heterotic effects for grain yield per plant (-27.55 - 53.69%), number of pods per plant (-30.59 - 54.95%), number of fruiting branches per plant (-16.88 - 46.92%), number of grains per pod (-12.14 - 21.94%) and 100-seed weight (-25.66 - 15.83%).

Singh *et al.* (1990) and Waldia *et al.* (1991) noted variability in hundred seed weight and protein content in kabuli types, and in desi and kabuli types of chickpea respectively. Waldia *et al.* (1991) also noted that range for these two characters was higher for kabuli than for desi types.

Bahl *et al.* (1991) recorded data on seed yield and 10 yield-related traits for 130 kabuli and 199 desi lines of *Cicer arietinum* originating from the Indian sub-continent, Middle East, North Africa, America, Europe and the USSR. They observed greater plant height and lateness in flowering in USSR entries. Group means of USSR accessions, both desi and kabuli, differed significantly from those of Indian varieties for majority of the characters. These observations indicated that the degree of expression of certain characters could be ascribed to specific areas, which led to area specific adaptations.

Singh and Rao (1991) evaluated 11 genotypes of chickpea (5 F_2s and 6 parents) for 10 yield components and observed substantial genetic variability for all characters. They suggested the direct selection for seed yield per plant and its components to bring improvement in hybrids. Panchbhai *et al.* (1992) evaluated 12 F_4 populations together with controls for yield and seven component traits and observed differences due to crosses for grain yield.

Chavan *et al.* (1994) found that variability was high for number of pods per plant (35 - 169) followed by seed yield per plant (8 - 35 g) and branches per plant (5 - 15) while evaluating 70 genotypes. Rao *et al.* (1994) observed variability for all characters studied in 44 varieties of gram and recorded maximum variability for 100-seed weight followed by secondary branches per plant, pods per plant and seed yield per plant. Rana *et al.* (1995) studied 87 chickpea genotypes of indigenous and exotic origin for seed yield and yield related characters and observed considerable variation for all the characters except plant height, seeds per pod and protein content.

Gil *et al.* (1996) observed significant differences between desi and kabuli types for 100-seed weight (12.9 - 52.6 g) and seed coat thickness (0.04 - 0.17 mg/mm^2) in a study on 50 chickpea accessions (26 kabuli and 24 desi) and noted no difference for protein content between the two types. They suggested improvement in protein content through plant breeding in the two chickpea types, by using lines with stable and high protein content.

Jahagirdar *et al.* (1996) analysed 28 chickpea F_1 progenies and observed a wide range of variation for all the characters studied. The variation was high for number of pods per plant (28 - 56) and low for number of primary branches per plant (3.6 - 6.4). The character showing high range of variation provided scope for selecting the desirable types.

Patil and Meshram (1996) studied three promising mutants and two local genotypes of chickpea and found significant differences among genotypes for yield contributing characters and yield. 100-seed weight ranged from 12.0 - 32.9 g and seed yield from 13.59 - 17.63 g.

Patil *et al.* (1996) studied the nature and magnitude of variability generated in intra (desi x desi and kabuli x kabuli) and inter (desi x kabuli) groups of crosses and found higher amount of variability in the inter group cross than in intra-group crosses for primary branches, pods per plant, seeds per plant, seeds per pod, test weight and yield per plant. Desi x desi cross exhibited higher variance for plant height and secondary branches whereas kabuli x kabuli cross exhibited higher variance for plant spread and internodal distance.

Considerable variation has been reported in literature for yield and yield related traits, seed protein content and fibre content in chickpea genotypes indicating scope for improvement by direct selection for these characters. Variation was higher in desi x kabuli crosses. It was suggested that seed protein content could be improved through plant breeding in two chickpea types i.e. desi and kabuli, by using lines with stable and high protein content.

2.6 Heterosis

Heterosis is the increase or decrease of F_1 hybrid over its better parent or mid parental value. Chickpea is a self-pollinated crop and the scope for exploitation of hybrid vigour

will depend on the mechanism, direction and magnitude of heterosis. In chickpea, the first report of hybrid vigour for pods per plant was given by Pal (1945) and later heterosis was demonstrated by Ramanujam *et al.* (1964). The study of heterosis also will have a direct bearing on the breeding methodology to be employed for varietal improvement in this crop. The review of literature for heterosis in chickpea is presented hereunder.

Arora and Pandya (1987) analysed data on seed yield per plant and five related traits from a series of crosses and revealed that nine crosses had significantly higher yields than the yield of the best parent and expressed significant positive heterosis for other traits. They observed that heterosis was high in local x foreign and desi x kabuli crosses and was highest between high-yielding and low-yielding parents, and between low-yielding parents.

Heterosis for seed yield over the mid parent and better parent was observed in the hybrids of many crosses by many workers namely Tewari and Pandey (1987), Kumar and Bahl (1988), Bahl and Kumar (1989) and Shinde and Deshmukh (1993). Tewari and Pandey (1987) also observed heterosis over better parent for pods per plant, seeds per plant and seeds per pod in different crosses. Kumar and Bahl (1988) found that heterosis for seed yield was largely dependent on heterosis for pods per plant and obtained most of the heterotic hybrids from combinations of parents with low GCA effects.

Salimath *et al.* (1988) estimated heterosis for seed protein content in 45 F_1 hybrids and found that three crosses showed significant and positive mid parent heterosis. Out of these three crosses, two also showed significant and positive better parent heterosis.

Mian and Bahl (1989) and Arora (1990) performed Mahalanobis D^2 analysis of yield components in parents and hybrids. Mian and Bahl (1989) obtained significant and positive mid parent heterosis for seed yield and some of its components with parents separated by medium D^2 values. Arora (1990) obtained best heterotic hybrids for seed yield from parents belonging to two different groups wherein the parents were classified into groups based on genetic divergence.

Pandey and Tiwari (1989) studied heterosis in 10 yield related characters in parents, F_1s, F_2s and backcrosses of five *Cicer arietinum* crosses and found no uniform trend in the manifestation of heterosis in all the crosses for different characters. Three crosses exhibited significant heterosis over better parent for pod number, seed number and yield. High heterosis noted in one cross for yield was 29.02%. They ruled out the possibility of heterosis breeding in this crop due to its floral biology and the presence of marginal heterosis.

Rao and Chopra (1989) worked on a cross of desi (BG 256) with two kabuli types (ICC 32 and K_4) to measure improvements in yield and yield related traits in F_1 relative to the mid parental value and better parent. They obtained high heterosis and heterobeltiosis for yield per plant, seed yield from secondary and tertiary branches, number of primary

and secondary branches, plant height and weight, number of pods per plant and test weight per unit volume in the cross BG 256 x ICC 32. The other cross was better for number of seeds per plant, number of seeds per pod, number of tertiary branches and seed yield from primary branches.

Khan *et al.* (1990) concluded that hybrids of seven genotypes studied exhibited high mid parent heterosis for grain yield. They suggested the traditional approach of making a large number of crosses among the parents selected for valuable traits and evaluating them for yield and desirable characters as the most effective approach to the development of chickpea.

Shinde and Deshmukh (1990) made diallel crosses using six varieties and obtained high heterosis over better parent for number of pods per plant (54.95%) followed by grain yield (53.69%), number of fruiting branches (46.92%), number of grains per pod (21.94%) and 100-grain weight (15.83%). The overall mean heterosis was high for grain yield per plant (25.25%) followed by number of pods per plant (23.96%) and number of fruiting branches per plant (21.30%). They associated high heterosis for grain yield with high heterosis for number of fruiting branches and number of pods per plant, and reported negative heterosis for grains per pod and 100-grain weight.

Bejiga and Singh (1991) and Gumber *et al.* (1992) studied parents and F_1s, and observed that parents of genetically divergent origin produced greater hybrid vigour or maximum heterosis and transgressive segregants than those of similar origin. Gumber

et al. (1992) later selected seven parents with moderate genetic divergence and comparatively high performance and crossed to produce 21 crosses in which five crosses had high mean performance for important yield components and seven crosses showed heterobeltiosis ranging from 12.1 - 50.1% for seed yield.

Satija *et al.* (1993) evaluated 28 F_1 hybrids from crosses of eight parents and found significant differences between hybrids, with some crosses showing good results for seed weight and pod number.

Kamatar *et al.* (1996) observed high positive heterosis for pod number (144.3%) followed by seed yield per plant (130.5%), total number of branches per plant (120.5%) and protein content (47.1%) in 66 hybrids and their 17 diverse parents. He indicated that primary branches per plant, total number of branches per plant and number of pods per plant were major contributors to seed yield.

Patil *et al.* (1996) carried out a study on parents, F_1, F_2 and F_3 generations of intra (desi x desi and kabuli x kabuli) and inter (desi x kabuli) group of crosses in chickpea and obtained a higher magnitude of heterosis for seed yield and components in inter than intra-group crosses. Heterosis for pods per plant contributed considerably to seed yield heterosis.

Thus, most workers indicated some heterosis for seed yield, yield related traits and protein content in chickpea. High heterosis was observed in crosses involving

genetically divergent parents and in desi x kabuli crosses compared to desi x desi and kabuli x kabuli crosses. Some workers ruled out the possibility of heterosis breeding in chickpea due to its floral biology and the presence of marginal heterosis.

Note : Heterosis and Heterobeltiosis used by the various scientists are referred to as Mid parent heterosis and Better parent heterosis in the present study.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present investigation was undertaken to study the inheritance of flower colour, seed protein and crude fibre content and to determine the association of these characters with yield and yield contributing traits in chickpea. The differences for these traits and extent of heterosis were also studied. The F_1 and F_2 generations of two chickpea crosses and their respective parents (one parent being common to both crosses) were included for this study.

The experiment was conducted during the *Rabi* (post-rainy season) 1997/98 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru, A. P. ICRISAT Center is located at an altitude of 545 m above mean sea level at a latitude of 17°32'N and longitude of 78°16'E. The weather data during the crop growth period is given in Appendix C. The research material was provided by Chickpea Breeding Unit at ICRISAT. Details of the materials and methods followed in this experiment are furnished hereunder.

3.1 MATERIALS

The experiment was conducted with three genotypes P 9623, RS 11 and T 39-1 involved in two crosses. T 39-1 was a common male parent for both the crosses. P 9623 is a white flowered, large seeded kabuli type chickpea having owl's head shaped salmon white seeds with moderate protein content. RS 11 has white flower colour, medium sized light brown desi seeds and low protein content. T 39-1 is a high protein germplasm accession with blue

Table 1: Characteristic features of the parents P 9623, RS 11 and T 39-1.

Character	P 9623	RS 11	T 39-1
Origin	U.S.A	India	India
Accession No.	4854	4992	5912
Growth habit	Semi erect	Semi erect	Semi erect
Flower colour	White	White	Blue
Pod size	Large	Medium	Small
Seed size	Large	Medium	Small
Seed type	Kabuli	Desi	Intermediate
Seed shape	Owl's head	Angular	Pea
Seed coat colour	Salmon white	Yellow brown	Gray
Seed surface	Smooth	Rough	Smooth
Seed protein content	Moderate	Low	High
Crude fibre content	Low	High	Medium
Maturity	Long	Medium	Long

Source: Chickpea Breeding Unit, ICRISAT, Patancheru, A.P.

flowers and gray coloured small pea shaped seeds (Table 1). The crosses P 9623 x T 39-1 and RS 11 x T 39-1 were made in the *Rabi* season 1995 to get the F_1 generations. The F_1 seeds were grown during the *Rabi* season 1996 to obtain the F_2 seeds. These F_2 seeds were taken as the material for the present investigation. The F_1 generations for the study were obtained in the glass house and sown during the 1997/98 *Rabi* season.

3.2 METHODS

The parental, F_1 and F_2 seeds of the two crosses were sown on 14 October 1997 on deep vertisols under conserved soil moisture conditions. They were sown on ridges 60 cm apart in an unreplicated block. The plot sizes were 10 rows, 4 m long, 60 cm apart for each F_2 and one row each for parents and F_1s. The seeds were planted at 20 cm within the row.

Plant protection measures and other cultural operations necessary to raise a healthy crop were taken up.

3.3 COLLECTION OF DATA

In the F_2 generation of the cross P 9623 x T 39-1, flower colour was recorded on 160 random competitive plants to observe the segregation pattern of flower colour. Data on yield and yield contributing characters were recorded on 117 random competitive plants after discarding damaged and disease effected plants. In the other cross RS 11 x T 39-1, flower colour was observed on 150 plants. The other data were recorded on 90 plants after discarding damaged and disease effected plants. Similarly, all the required data were recorded on 20 plants in each parent and 10 plants in each F_1 for two crosses.

Single plant data were recorded for the following characters on parents, F_1s and F_2s.

3.3.1 Flower colour

Colour of the freshly opened flower i.e. pink, blue or white was recorded.

3.3.2 Plant height (cm)

Height of the plant in cm was measured and recorded from the soil surface to the tip of the longest branch at the time of maturity.

3.3.3 Number of primary branches per plant

At maturity, number of branches originating from the base of the plant was counted and recorded for each of the selected plant.

3.3.4 Number of secondary branches per plant

At maturity, the number of branches originating from all the primary branches was counted and recorded.

3.3.5 Number of pods per plant

Total number of pods, both filled and unfilled, on all branches of a plant was counted and recorded.

3.3.6 Number of seeds per plant

Total number of seeds, both filled and ill-filled, obtained after threshing of all pods of a plant was counted and recorded.

3.3.7 Number of seeds per pod

Number of seeds per pod was obtained by the formula

$$\frac{\text{Total number of seeds per plant}}{\text{Total number of pods per plant}}$$

3.3.8 100-seed weight (g)

Weight of 100 seeds in g was obtained by using the formula

$$\frac{\text{Seed yield per plant (g)}}{\text{Total number of seeds per plant}} \times 100$$

3.3.9 Seed yield per plant (g)

All the seeds from each plant were weighed and recorded in g.

3.4 CHEMICAL ANALYSIS

3.4.1 Seed protein content (%)

The protein content in the seeds of individual plant was determined by multiplying the total Nitrogen content (N) in the seeds obtained by Technicon autoanalyser (TAA) with factor 6.25. This analysis was done in the Crop Quality Service Laboratory at ICRISAT by adopting the following procedure.

The seeds of each plant were ground in Udy cyclone grinding mill and passed through a 0.4 mm mesh to obtain chickpea flour. Sixty mg flour of chickpea was weighed and transferred to a technicon digestion tube (75 ml). 3 ml of acid mixture consisting of 5 parts (v/v) orthophosphoric acid in 100 parts of sulphuric acid and one kjel tab containing 1.5 g K_2SO_4 and 7.5 mg Selenium were added to each tube. Each set of 40 tubes had one blank, one check standard, two random samples selected from preceding set and 36 regular (unknown) samples. The set was heated in block digestor maintained at 360°C for 1 hr 15 min for digestion. The digest was then cooled and dissolved in minimum amount of water. Then the volume was made to 75 ml and the solution was mixed thoroughly. Then the aliquot from each tube was transferred into a Technicon sample cup for analysis using TAA.

Calibration:

For calibration, alkaline buffer (alkaline sodium potassium tartarate), hypochlorite (NaOCl), alkaline phenol and wash solution were run through the respective tubings for 15 minutes. Then ammonium sulphate standards (blank, 20, 30 and 50 ppm N) were run by switching 'on' the sampler. Slope was established by adjusting 30 ppm to 54 divisions on TAA chart by using base line and calibration knob. Slope was checked for other Nitrogen standards. Samples were run by switching on rotating disc. Sample peak heights were noted.

$$N\% = \frac{\text{sample peak height x 75 x 100}}{\text{slope x 1000 x sample weight (mg)}}$$

Protein content = N% x 6.25

3.4.2 Crude fibre content (%)

Crude fibre content (%) was determined by estimating the fibre content of the seed as follows:

Crude fibre estimation:

Chickpea flour for each plant was prepared by grinding seeds in Udy cyclone mill and passing through 0.4 mm mesh. 2 g of chickpea flour and 1 g of asbestos were weighed into a special type (crude fibre) beaker. 200 ml hot solution of 0.255 N sulphuric acid and a few boiling chips were added. The beaker was placed on a preheated plate of the digestion apparatus and the sample was digested for 30 min, rotating the beaker periodically to keep away the solids from adhering to the sides. Sample was filtered through California modified Buchner funnel using a vaccum pump. Residue was then washed with hot water until washings were free from acid. Then the residue was transferred back into the beaker with hot 0.313 N sodium hydroxide solution. Again the sample was digested for 30 min by placing on the heater. Then the sample was again filtered through California modified funnel and the residue was washed with hot water until the washings were free from alkali and finally washed with alcohol. Then the residue was transferred into a clean porcelain crucible and dried at 100°C overnight. The crucible was transferred into a desiccator and cooled to room temperature and weighed (w_1). The residue was ignited in a muffle furnace at 600°C for 30 min. Then the crucible was transferred into a desiccator and cooled to room temperature and again weighed (w_2). A blank also was run.

Weight of the crude fibre = $(w_1 - w_2)$ - blank.

$$\% \text{ Crude fibre} = \frac{\text{weight of the crude fibre}}{\text{weight of the sample (2g)}} \times 100$$

3.5 STATISTICAL ANALYSIS

The data recorded on various characters studied were subjected to the following statistical analysis.

3.5.1 χ^2 test of goodness of fit

It is a test of wide applicability to numerous problems of significance in frequency data. χ^2 is a measure of actual divergence of the observed from the expected frequency (Panse and Sukhatme, 1967).

χ^2 test was done to test the goodness of fit of the observed ratio of segregation for flower colour character in both the crosses studied. The formula given by Kapur and Saxena (1969) was used.

$$\chi^2 = \sum_{i=1}^{n} \frac{(o_i - e_i)^2}{e_i}$$

o_i = observed frequency in i^{th} class of the distribution

e_i = expected frequency in i^{th} class of the distribution

Σ = Summation of 'n' number of classes

Test of significance:

Table values of χ^2 at 2 degrees of freedom were noted at 5% and 1% level of significance. The calculated χ^2 values were less than the table values at 2 degrees of freedom. Hence, it was concluded as non-significant difference between observed and expected frequencies and therefore the fit observed for the ratio was good.

3.5.2 Correlation coefficients

Changes in one variable may be accompanied by changes in another and that a relation exists between the two, which indicates a correlation between the two variables. Correlation coefficient (r) is a measure of the degree of closeness of the linear relationship between two variables.

Simple correlation coefficients among seed protein content, crude fibre content, yield and yield-related traits were worked out using the formula suggested by Panse and Sukhatme (1967).

$$\text{Correlation coefficient (r)} = \frac{\sigma xy}{\sigma x \,.\, \sigma y}$$

$$\sigma xy = \frac{\sum f (x - \bar{x})(y - \bar{y})}{N} = \frac{\sum f \,.\, dx \,.\, dy}{N}$$

σxy = mean product moment or the covariance between x and y

σx = standard deviation of x

σy = standard deviation of y

dx & dy = deviations

$$\sigma x = \frac{\sqrt{\Sigma f dx^2}}{N} \qquad \sigma y = \frac{\sqrt{\Sigma f dy^2}}{N}$$

Significance of the correlation coefficient =

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

r is the estimate obtained from 'n' pairs. The significance of correlation was tested by referring to the standard 't' table given by Snedecor and Cochran (1968) at 5% and 1% levels of significance.

3.5.3 Test of significance of means

Test of significance is a procedure for distinguishing whether the observed difference connotes any real difference among groups or can be ascribed to mere sampling fluctuations.

The test of significance is a method of making due allowance for the sampling fluctuation affecting the results of experiments or observations. 't' and 'Z' tests (based on the sample size) were used to test the significance of difference between two means for seed protein content, crude fibre content, yield contributing traits and seed yield among parents and between crosses respectively (Kapur and Saxena, 1969).

$$t = \frac{|\bar{P}_1 - \bar{P}_2|}{s\sqrt{1/n_1 + 1/n_2}}$$ (if sample size is < 30)

where,

$\bar{P}_1$ = mean of parent 1

$\bar{P}_2$ = mean of parent 2

s = standard deviation of the population

n_1 and n_2 are size of samples for parent 1 and 2 respectively

$$s = \frac{1}{n_1 + n_2 - 2}[(n_1 - 1)\, s_1^2 + (n_2 - 1)s_2^2]$$

s_1 and s_2 are the standard deviations for parent 1 and 2 respectively.

$$Z = \frac{|\bar{P}_1 - \bar{P}_2|}{\sqrt{(s_1^2 / n_1) + (s_2^2 / n_2)}} \quad \text{(if sample size is > 30)}$$

$$s_1 = \sqrt{1/ n_1 [\sum P_1^2 - (\sum P_1)^2 / n_1]}$$

$$s_2 = \sqrt{1/ n_2 [\sum P_2^2 - (\sum P_2)^2 / n_2]}$$

where,

$\bar{P}_1$ = mean of parent 1

$\bar{P}_2$ = mean of parent 2

s_1 & s_2 = standard deviations of the samples of size n_1 and n_2 respectively.

3.5.4 Estimation of heterosis

Heterosis can be grouped under two categories:

1. Increase or decrease in hybrid vigour over the mid parental value called mid parent heterosis.
2. Increase or decrease in hybrid vigour over better parental value called better parent heterosis.

$$\text{Mid parent heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

where, $\overline{F_1}$ = Mean value of F_1

$\overline{MP}$ = Mean value of mid parent

$$\text{Better parent heterosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where, $\overline{F_1}$ = mean value of F_1

$\overline{BP}$ = mean value of better parent

The magnitude of heterosis for seed yield, yield components, seed protein and crude fibre content in each cross was worked out on the basis of the formula mentioned above.

RESULTS

CHAPTER IV

RESULTS

An experiment was conducted in the *Rabi* (post-rainy season) 1997/98 to study the inheritance of flower colour, seed protein content, crude fibre content, correlations among seed yield and yield contributing characters, differences among parents and between crosses and the extent of heterosis for the characters studied in chickpea (*Cicer arietinum* L.). The studies were made on parents and F_1 and F_2 generations of two selected crosses namely P 9623 x T 39-1 and RS 11 x T 39-1 involving three parents P 9623, RS 11 and T 39-1. The data were recorded on individual plants for parents and F_1 and F_2 generations of both the crosses for 11 characters namely flower colour, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per plant, number of seeds per pod, 100-seed weight, seed protein content, crude fibre content and seed yield per plant. The results are presented under the following headings:

4.1 Inheritance of flower colour

4.2 Inheritance of seed protein content

4.3 Inheritance of crude fibre content

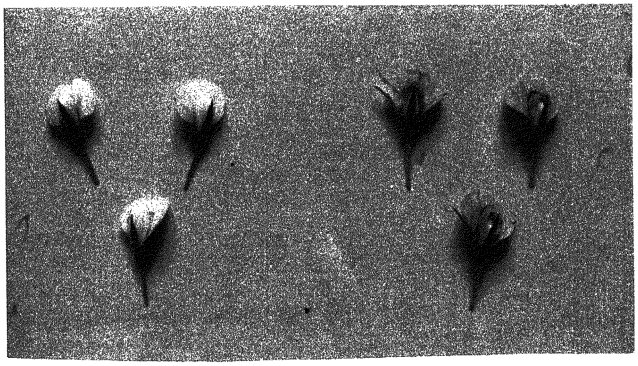
4.4 Correlation coefficients

4.5 Variability for characters

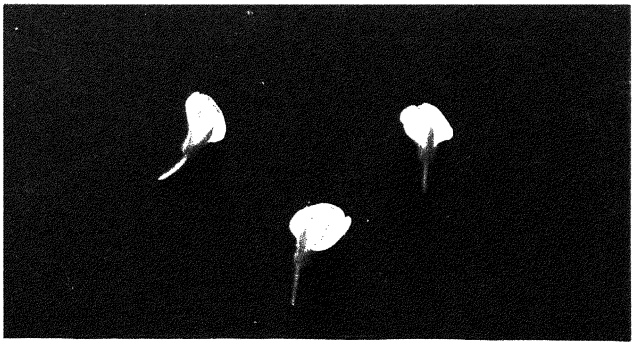
4.6 Heterosis

4.1 Inheritance of flower colour

Inheritance of flower colour (pink, blue and white) was studied in the parents and F_1 and F_2

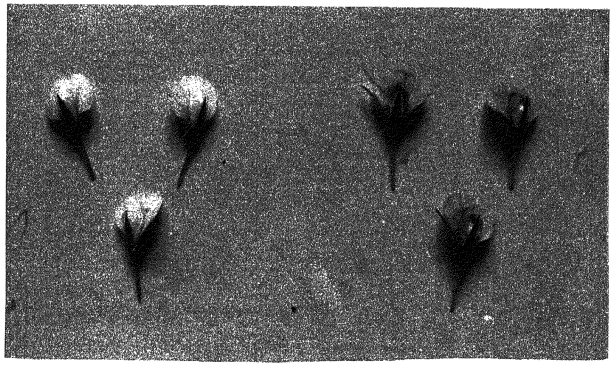


P 9623 T 39-1



F_1 (P 9623 x T 39-1)

Plate 1 : Flower colour variation in the parents P 9623 and T 39-1 and their F_1



RS 11 T 39-1

F_1 (RS 11 x T 39-1)

Plate 2 : Flower colour variation in the parents RS 11 and T 39-1 and their F_1.

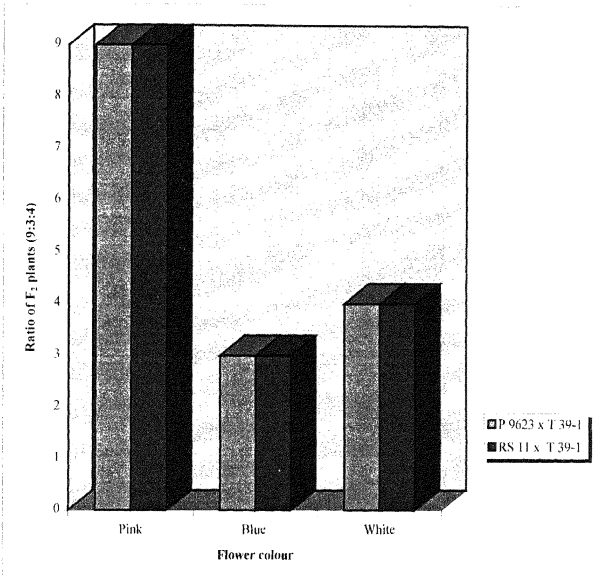


Figure 2 : Ratio of three flower colours for F_2 generations of the crosses P 9623 x T 39-1 and RS 11 x T 39-1.

Table 2 : Segregation for flower colour in the F_2 generation of two crosses of chickpea, *Rabi* 1997/98.

Cross	Parent / Generation	Flower colour	Expected ratio (F_2)	No. of plants		χ^2
				Observed	Expected	
P 9623 x T 39-1	P 9623	White				
	T 39-1	Blue				
	F_1	Pink				
	F_2	Pink	9	77	90.00	4.44^{NS}
		Blue	3	34	30.00	
		White	4	49	40.00	
RS 11 x T 39-1	RS 11	White				
	T 39-1	Blue				
	F_1	Pink				
	F_2	Pink	9	88	84.38	1.18^{NS}
		Blue	3	30	28.12	
		White	4	32	37.50	

NS = Non-significant

generations of two crosses of chickpea namely P 9623 x T 39-1 and RS 11 x T 39-1 wherein P 9623 and RS 11 are both white flowered types and T 39-1 is a blue flowered type. The results are given in Table 2.

4.1.1 Cross I: P 9623 x T 39-1

The cross between P 9623 (white) and T 39-1 (blue) produced pink F_1 indicating interaction of blue with white flower colour (Plate 1). In the F_2 generation, the data of the three flower colours taken on 160 plants fitted well to the ratio of 9 pink : 3 blue : 4 white ($\chi^2 = 4.44$; $0.05 > P > 0.01$).

4.1.2 Cross II: RS 11 x T 39-1

The cross between RS 11 (white) and T 39-1 (blue) also produced pink F_1 (Plate 2). In the F_2 generation, the data on 150 plants fitted well to the ratio of 9 pink : 3 blue : 4 white flower colours ($\chi^2 = 1.18$; $0.05 > P > 0.01$). The results for both the crosses showed a supplementary type of gene action for flower colour (Figure 2).

4.2 Inheritance of seed protein content

Seed protein content was determined for the parents and F_1 and F_2 generations of the two crosses P 9623 x T 39-1 and RS 11 x T 39-1. The results are given in Table 3.

4.2.1 Cross I: P 9623 x T 39-1

The mean seed protein content of P 9623 and T 39-1 was 24.32% and 30.24% respectively which were significantly different from each other. The F_1 value was 23.51% $\pm$ 0.640,

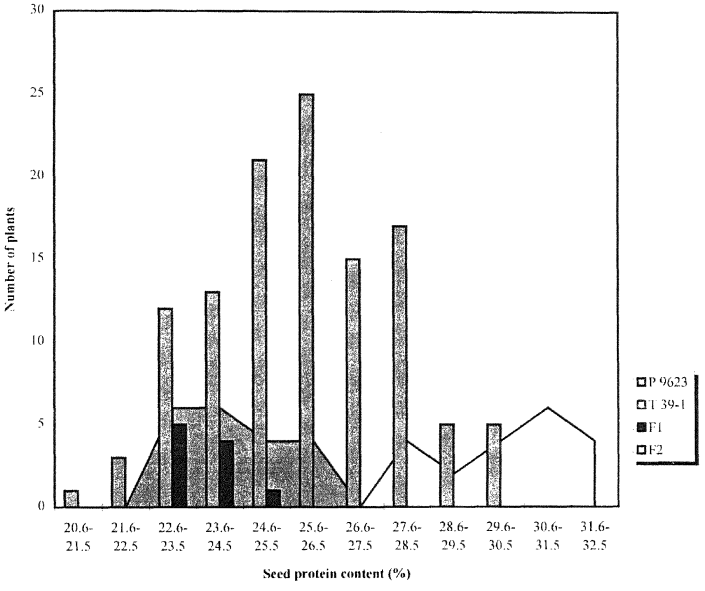


Figure 3 : Frequency distribution for seed protein content in parental, F_1 and F_2 generations for the cross P 9623 x T 39-1.

which was almost equal to the low protein parent indicating the dominance for low protein content. Mean value for the F_2 generation was 25.94% $\pm$ 0.182, which was lower than the mid parental value (27.28%) and nearing the low protein parent.

The frequency distribution for seed protein content for the parents and F_1 and F_2 generations is presented in Figure 3. Near normal distribution was found for F_2 generation of this cross, which ranged from 21.40 - 30.50%, which suggested multigenic control of this character. The seed protein content for the F_2 extended beyond the low protein parent indicating non-isodirectional distribution of genes for high and low seed protein content.

4.2.2 Cross II: RS 11 x T 39-1

RS 11 showed a mean seed protein content of 22.47%, while the high protein parent, T 39-1 had 30.24%. The F_1 of this cross showed a mean of 21.72% $\pm$ 0.650, which was almost equal to the low protein parent indicating dominance for low protein content. The mean of the F_2 generation was 24.32% $\pm$ 0.224, which was lower than the mid parental value (26.36%) and nearing the low protein parent.

The seed protein content values for parents and F_1 and F_2 generations of this cross are presented in the form of a frequency distribution in Figure 4. The F_2 distribution was near normal and showed slight skewness towards the low protein parent reflecting the multigenic control of the character and existence of dominance for low seed protein content. The F_2 seed protein content values ranged from 20.50 - 30.10% showing absence of transgressive segregation which might be due to iso-directional distribution of genes for low

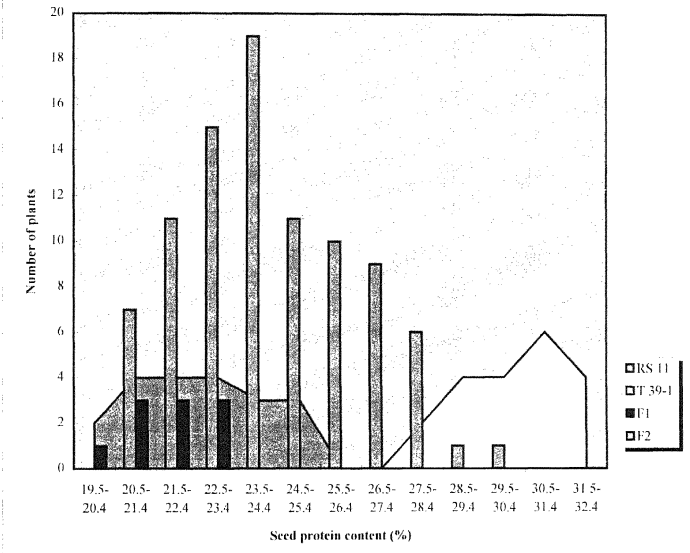


Figure 4 : Frequency distribution for seed protein content in parental, F_1 and F_2 generations for the cross RS 11 x T 39-1.

Table 3 : Seed protein and crude fibre content for the parental, F_1 and F_2 generations of two crosses of chickpea, *Rabi* 1997/98.

Cross	Parent / Generation	Seed protein content (%)	Range	Crude fibre content (%)	Range
P 9623 x T 39-1	P 9623	24.32 ± 0.554	23.10 - 26.30	3.63 ± 0.256	3.02 - 4.49
	T 39-1	30.24 ± 0.440	27.70 - 31.80	4.93 ± 0.070	4.60 - 5.20
	F_1	23.51 ± 0.640	22.60 - 24.90	5.23 ± 0.260	4.90 - 5.80
	F_2	25.94 ± 0.182	21.40 - 30.50	4.19 ± 0.083	2.52 - 6.50
RS 11 x T 39-1	RS 11	22.47 ± 0.520	20.40 - 24.90	9.78 ± 0.160	9.10 - 10.30
	T 39-1	30.24 ± 0.440	27.70 - 31.80	4.93 ± 0.070	4.60 - 5.20
	F_1	21.72 ± 0.650	20.20 - 23.10	9.26 ± 0.160	8.70 - 9.80
	F_2	24.32 ± 0.224	20.50 - 30.10	8.48 ± 0.125	5.20 - 11.60

and high seed protein content and the presence of a larger number of genes segregating for this character.

4.3 Inheritance of crude fibre content

The crude fibre content of chickpea seed was determined for the parents and F_1 and F_2 generations of the two crosses studied namely P 9623 x T 39-1 and RS 11 x T 39-1. The results of the investigation are given in Table 3.

4.3.1 Cross I: P 9623 x T 39-1

P 9623, a kabuli type showed a range of 3.02 - 4.49% with a mean value of 3.63% for the crude fibre content. The parent T 39-1, which is of intermediate type had a mean crude fibre content of 4.93% with a range of 4.60 - 5.20%. The F_1 showed a value of 5.23% $\pm$ 0.260, which was almost equal to the high parent indicating dominance for high fibre content. The F_2 generation of this cross varied from 2.52 - 6.50% with a mean value of 4.19% $\pm$ 0.083, which was approaching mid parental value (4.28%) and lower than F_1 mean value.

The frequency distribution for parents and F_1 and F_2 generations is presented in Figure 5. This cross showed a near normal distribution in the F_2 generation suggesting multigenic control of the character. The range for F_2 extended beyond both the parents. Transgressive segregation was observed towards both the parents, which indicated substantial degree of recombination between the genomes of two parents. The recombination resulted in complementation when they segregated in the F_2 generation.

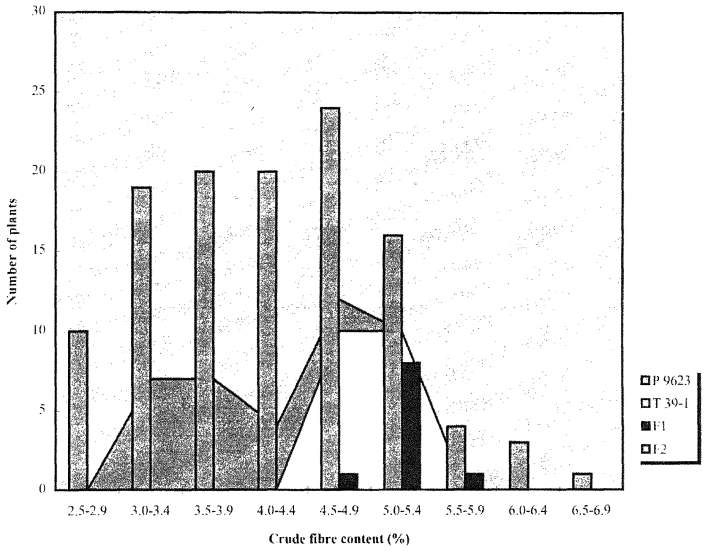


Figure 5 : Frequency distribution for crude fibre content in parental, F_1 and F_2 generations for the cross P 9623 x T 39-1.

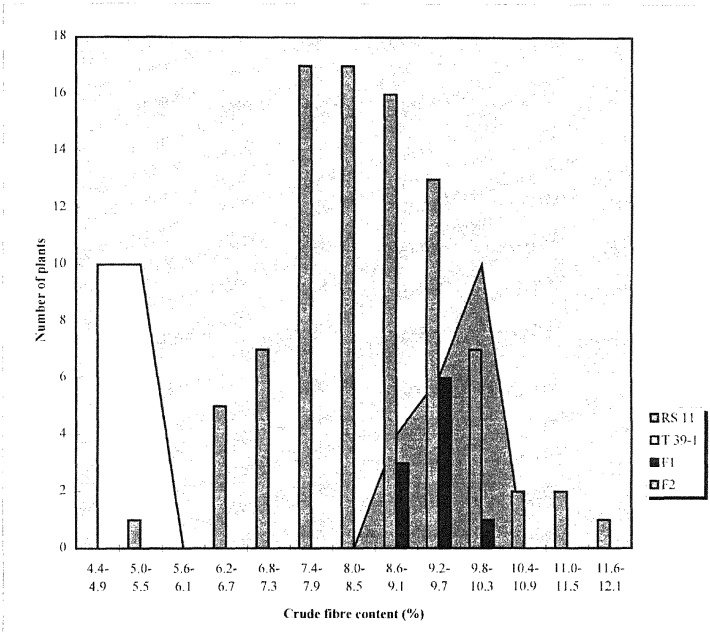


Figure 6 : Frequency distribution for crude fibre content in parental, F_1 and F_2 generations for the cross RS 11 x T 39-1.

4.3.2 Cross II: RS 11 x T 39-1

RS 11 had a mean crude fibre content of 9.78% and a range of 9.10 - 10.30%, and T 39-1 had a mean of 4.93% and a range of 4.60 - 5.20%. The F_1 showed a mean value of 9.26% $\pm$ 0.160, which was higher than the mid parental value of 7.36% and more towards high parent, RS 11 suggesting dominance for high crude fibre content. The mean crude fibre content in the F_2 generation of 8.48% (range : 5.20 - 11.60%) although slightly lower than F_1 value but was higher than the mid parental value and approaching the high parent.

The frequency distribution for parents and F_1 and F_2 generations is presented in Figure 6. Multigenic control of the character was suggested owing to the near normal frequency distribution in F_2. The F_2 range extended beyond the high parent. Transgressive segregation towards high crude fibre content was probably due to non-isodirectional distribution of genes for high and low crude fibre content in the parents.

4.4 Correlation coefficients

Phenotypic correlation coefficients were computed for the F_2 generation for both the crosses and within white, pink and blue flowered plants for each cross.

4.4.1 Cross I: P 9623 x T 39-1

Phenotypic correlation coefficients were worked out for yield and yield contributing characters studied in individual F_2 plants in the cross P 9623 x T 39-1 as a whole and in white, pink and blue flowered plants. The results are presented in Table 4.

Table 4 : Phenotypic correlation matrix for 10 characters for the chickpea cross P 9623 x T 39-1, *Rabi* 1997/98.

		Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per plant	No. of seeds per pod	100-seed weight (g)	Seed Protein content (%)	Crude fibre content (%)	Seed yield per plant (g)
Plant height(cm)	1	1.000	0.260**	0.205*	-0.046	-0.086	-0.198*	0.207*	-0.006	-0.288**	-0.058
	2	1.000	0.155	0.164	-0.369*	-0.506**	-0.337*	0.512**	-0.132	-0.291	-0.413*
	3	1.000	0.201	0.092	-0.038	-0.093	-0.206	0.109	-0.029	-0.130	-0.062
	4	1.000	0.560**	0.477*	0.235	0.263	0.302	0.272	-0.072	-0.279	0.286
No. of primary branches per plant	1		1.000	0.836**	0.434**	0.356**	-0.248**	0.047	0.084	-0.208*	0.377**
	2		1.000	0.845**	0.374*	0.217	-0.362*	0.083	-0.019	-0.263	0.242
	3		1.000	0.832**	0.438**	0.331*	-0.359**	-0.016	0.122	-0.101	0.352**
	4		1.000	0.823**	0.557**	0.568**	0.270	0.141	0.126	-0.130	0.569**
No. of secondary branches per plant	1			1.000	0.398**	0.308**	-0.256**	0.004	0.065	-0.175	0.315**
	2			1.000	0.272	0.111	-0.379*	0.107	-0.108	-0.196	0.140
	3			1.000	0.471**	0.347**	-0.328*	-0.035	0.092	-0.089	0.377**
	4			1.000	0.448*	0.452*	0.219	-0.036	0.101	0.027	0.395
No. of pods per plant	1				1.000	0.941**	-0.098	-0.178	0.058	-0.071	0.897**
	2				1.000	0.826**	-0.245	-0.345*	0.142	-0.266	0.847**
	3				1.000	0.944**	-0.122	-0.102	-0.061	0.083	0.895**
	4				1.000	0.977**	0.080	-0.034	0.050	-0.182	0.946**
No. of seeds per plant	1					1.000	0.189*	-0.222*	0.024	-0.007	0.939**
	2					1.000	0.226	-0.605**	0.097	-0.092	0.911**
	3					1.000	0.174	-0.124	-0.095	0.154	0.939**
	4					1.000	0.260	0.046	0.006	-0.220	0.976**
No. of seeds per pod	1						1.000	-0.179	-0.185*	0.144	0.140
	2						1.000	-0.462**	-0.148	0.245	0.073
	3						1.000	-0.134	-0.188	0.221	0.128
	4						1.000	0.348	-0.311	- 0.314	0.271
100-seed weight (g)	1							1.000	-0.301**	-0.357**	0.065
	2							1.000	-0.075	-0.332*	-0.300
	3							1.000	-0.195	-0.487**	0.173
	4							1.000	-0.441*	-0.549**	0.215
Seed protein content (%)	1								1.000	0.133	-0.109
	2								1.000	0.239	0.077
	3								1.000	0.192	-0.205
	4								1.000	0.345	-0.067
Crude fibre content (%)	1									1.000	-0.093
	2									1.000	-0.219
	3									1.000	-0.011
	4									1.000	-0.295
Seed yield per plant (g)	1										1.000
	2										1.000
	3										1.000
	4										1.000

- 1= Phenotypic correlation matrix for the cross in general.
- 2= Phenotypic correlation matrix for the white flowered plants.
- 3= Phenotypic correlation matrix for the pink flowered plants.
- 4= Phenotypic correlation matrix for the blue flowered plants.

- * Significant at 5% level
- ** Significant at 1% level

4.4.1.1 Plant height

In this cross, plant height showed highly significant positive correlation with number of primary branches per plant (0.260**) and significant positive correlations with number of secondary branches per plant (0.205*) and 100-seed weight (0.207*). It also showed highly significant negative correlation with crude fibre content (-0.288**) and significant negative correlation with number of seeds per pod (-0.198*).

Within the white flowered plants in this cross, plant height had highly significant positive correlation with 100-seed weight (0.512**) and negative correlation with number of seeds per plant (-0.506**). It had significant negative correlations with number of pods per plant (-0.369*), number of seeds per pod (-0.337*) and seed yield per plant (-0.413*).

Among the pink flowered plants, plant height showed non-significant correlations with all other characters. In blue flowered plants, it showed highly significant and significant positive correlations with number of primary branches per plant (0.560**) and number of secondary branches per plant (0.477*) respectively. Plant height showed maximum correlation with number of primary branches per plant (0.560**) in blue flowered plants.

4.4.1.2 Number of primary branches per plant

Number of primary branches per plant exhibited highly significant positive association with plant height (0.260**), number of secondary branches per plant (0.836**), number of pods per plant (0.434**), number of seeds per plant (0.356**) and seed yield per plant (0.377**) in

the cross. It exhibited highly significant and significant negative association with number of seeds per pod (-0.248**) and crude fibre content (-0.208*) respectively.

White flowered plants showed highly significant positive association between number of primary branches per plant and number of secondary branches per plant (0.845**), and significant positive association between number of primary branches per plant and number of pods per plant (0.374*). Number of primary branches per plant had significant negative association with number of seeds per pod (-0.362*).

Pink flowered plants exhibited highly significant positive association of number of primary branches per plant with number of secondary branches per plant (0.832**), number of pods per plant (0.438**) and seed yield per plant (0.352**), and significant positive association with number of seeds per plant (0.331*). It had highly significant negative association with number of seeds per pod (-0.359**).

Blue flowered plants showed highly significant positive association of primary branches per plant with plant height (0.560**), number of secondary branches per plant (0.823**), number of pods per plant (0.557**), number of seeds per plant (0.568**) and seed yield per plant (0.569**). Number of primary branches per plant showed high positive association with secondary branches per plant in white flowered plants (0.845**).

4.4.1.3 Number of secondary branches per plant

Number of secondary branches per plant was correlated highly significantly and positively

with number of primary branches per plant (0.836**), number of pods per plant (0.398**), number of seeds per plant (0.308**) and seed yield per plant (0.315**), and significantly and positively with plant height (0.205*). It was highly significantly and negatively correlated with number of seeds per pod (-0.256**) in the whole cross.

Among the white flowered plants, it was highly significantly and positively correlated with number of primary branches per plant (0.845**), and significantly and negatively correlated with number of seeds per pod (-0.379*). Number of secondary branches per plant was correlated highly significantly and positively with number of primary branches per plant (0.832**), number of pods per plant (0.471**), number of seeds per plant (0.347**) and seed yield per plant (0.377**) in pink flowered plants. It was correlated significantly and negatively with number of seeds per pod (-0.328*).

Within the blue flowered plants, it was correlated highly significantly and positively with number of primary branches per plant (0.823**). Significant positive correlations were seen with plant height (0.477*), number of pods per plant (0.448*) and number of seeds per plant (0.452*). Maximum correlation of this character was seen with number of primary branches per plant in white flowered plants (0.845**).

4.4.1.4 Number of pods per plant

The correlations of number of pods per plant with number of primary branches per plant (0.434**), number of secondary branches per plant (0.398**), number of seeds per plant (0.941**) and seed yield per plant (0.897**) were highly significant and positive in this cross.

Highly significant positive correlations were seen with number of seeds per plant (0.826**) and seed yield per plant (0.847**), and significant positive correlation with number of primary branches per plant (0.374*) in white flowered plants. Significant negative correlations were seen with plant height (-0.369*) and 100-seed weight (-0.345*).

Highly significant positive correlations were seen with number of primary branches per plant (0.438**), number of secondary branches per plant (0.471**), number of seeds per plant (0.944**) and seed yield per plant (0.895**) in pink flowered plants.

In blue flowered plants, it's correlations were highly significant and positive with number of primary branches per plant (0.557**), number of seeds per plant (0.977**) and seed yield per plant (0.946**). Correlation was significant and positive with number of secondary branches per plant (0.448*). Correlation was maximum between number of pods per plant and number of seeds per plant in blue flowered plants (0.977**).

4.4.1.5 Number of seeds per plant

The association of number of seeds per plant with number of primary branches per plant (0.356**), number of secondary branches per plant (0.308**), number of pods per plant (0.941**) and seed yield per plant (0.939**) was highly significant and positive, while it was significant and positive with number of seeds per pod (0.189*). The association was significant and negative with 100-seed weight (-0.222*).

In white flowered plants, highly significant and positive association of number of seeds per plant was seen with number of pods per plant (0.826**) and seed yield per plant (0.911**). Highly significant negative association of number of seeds per plant was also observed with plant height (-0.506**) and 100-seed weight (-0.605**).

Among the pink flowered plants, highly significant positive association of this character was noted with number of secondary branches per plant (0.347**), number of pods per plant (0.944**) and seed yield per plant (0.939**), and significant positive association with number of primary branches per plant (0.331*).

Within the blue flowered plants, highly significant positive association of this character was observed with number of primary branches per plant (0.568**), number of pods per plant (0.977**) and seed yield per plant (0.976**). Association was significant and positive with number of secondary branches per plant (0.452*). Maximum association of number of seeds per plant was seen with pods per plant in blue flowered plants (0.977**).

4.4.1.6 Number of seeds per pod

Number of seeds per pod was correlated significantly and positively with number of seeds per plant (0.189*). It was correlated highly significantly and negatively with number of primary branches per plant (-0.248**) and number of secondary branches per plant (-0.256**). It was correlated significantly and negatively with plant height (-0.198*) and seed protein content (-0.185*) in this cross.

Among the white flowered plants, number of seeds per pod was correlated highly significantly and negatively with 100-seed weight (-0.462**). It was correlated significantly and negatively with plant height (-0.337*), number of primary branches per plant (-0.362*) and number of secondary branches per plant (-0.379*).

Among the pink flowered plants, this character was correlated highly significantly and negatively with number of primary branches per plant (-0.359**), and significantly and negatively with number of secondary branches per plant (-0.328*). Among the blue flowered plants, number of seeds per pod was not correlated significantly with any of the other characters.

4.4.1.7 100-seed weight

100-seed weight had significant positive correlation with plant height (0.207*). It had highly significant negative correlations with seed protein content (-0.301**) and crude fibre content (-0.357**), and significant negative correlation with seeds per plant (-0.222*) in this cross.

100-seed weight showed highly significant and positive correlation with plant height (0.512**) and negative correlations with number of seeds per plant (-0.605**) and number of seeds per pod (-0.462**). It showed significant negative correlations with number of pods per plant (-0.345*) and crude fibre content (-0.332*) in the white flowered plants.

100-seed weight showed highly significant negative correlation with crude fibre content only (-0.487**) in pink flowered plants, while it showed highly significant negative

correlation with crude fibre content (-0.549**) and significant negative correlation with seed protein content (-0.441*) in blue flowered plants.

4.4.1.8 Seed protein content

In the cross in general, seed protein content showed highly significant negative relationship with 100-seed weight (-0.301**) and significant negative relationship with number of seeds per pod (-0.185*).

This character showed non-significant relationship with other characters in white and pink flowered plants, while it showed significant negative relationship with 100-seed weight (-0.441*) in blue flowered plants.

4.4.1.9 Crude fibre content

Crude fibre content had highly significant negative relationship with plant height (-0.288**) and 100-seed weight (-0.357**) and significant negative relationship with number of primary branches per plant (-0.208*).

This character had significant negative relationship with 100-seed weight (-0.332*) in white flowered plants and highly significant negative relationship with 100-seed weight (-0.487** and -0.549**) in pink and blue flowered plants. This character had non-significant relationship with all the other characters.

4.4.1.10 Seed yield per plant

Seed yield per plant was highly significantly and positively correlated with number of primary branches per plant (0.377**), number of secondary branches per plant (0.315**), number of pods per plant (0.897**) and number of seeds per plant (0.939**) in this cross.

Among the white flowered plants, seed yield per plant was highly significantly and positively correlated with number of pods per plant (0.847**) and number of seeds per plant (0.911**), and significantly and negatively correlated with plant height (-0.413*).

Within the pink flowered plants, seed yield per plant was highly significantly and positively correlated with number of primary branches per plant (0.352**), number of secondary branches per plant (0.377**), number of pods per plant (0.895**) and number of seeds per plant (0.939**).

Within the blue flowered plants, it was correlated highly significantly and positively with number of primary branches per plant (0.569**), number of pods per plant (0.946**) and number of seeds per plant (0.976**). With all other characters, it was non-significantly correlated in all cases. Seed yield per plant showed maximum positive correlation with number of seeds per plant in blue flowered plants (0.976**).

4.4.2 Cross II: RS 11 x T 39-1

Phenotypic correlation coefficients were worked out for the characters studied on individual

Table 5 : Phenotypic correlation matrix for 10 characters for the chickpea cross RS 11 x T 39-1, *Rabi* 1997/98.

		Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per plant	No. of seeds per pod	100-seed weight (g)	Seed protein content (%)	Crude fibre content (%)	Seed yield per plant (g)
Plant height (cm)	1	1.000	0.379**	0.349**	0.261*	0.250*	-0.018	-0.022	0.076	-0.280**	0.221*
	2	1.000	0.000	0.284	0.315	0.386	0.104	-0.348	0.766*	-0.608	0.164
	3	1.000	0.304*	0.259	0.135	0.126	0.001	0.269*	-0.075	-0.266*	0.200
	4	1.000	0.433*	0.413*	0.410	0.439*	0.111	0.213	-0.202	-0.024	0.466*
No. of primary branches per plant	1		1.000	0.723**	0.335**	0.323**	0.045	-0.123	0.111	-0.130	0.284**
	2		1.000	0.804**	0.087	0.129	0.054	0.484	-0.216	0.067	0.235
	3		1.000	0.674**	0.396**	0.414**	0.162	0.035	0.017	-0.182	0.455**
	4		1.000	0.721**	0.164	0.145	0.014	0.051	-0.134	0.230	0.118
No. of secondary branches per plant	1			1.000	0.519**	0.476**	-0.027	-0.152	0.174	-0.234*	0.388**
	2			1.000	0.218	0.379	0.178	0.231	0.207	-0.190	0.315
	3			1.000	0.426**	0.404**	0.032	0.048	0.120	-0.276*	0.441**
	4			1.000	0.663**	0.561**	-0.030	-0.143	-0.090	0.044	0.434*
No. of pods per plant	1				1.000	0.883**	-0.188	-0.343**	0.248*	-0.104	0.741**
	2				1.000	0.925**	-0.294	-0.071	0.603	0.181	0.879**
	3				1.000	0.894**	-0.174	-0.229	-0.002	0.077	0.872**
	4				1.000	0.843**	-0.075	-0.145	-0.013	-0.282	0.706**
No. of seeds per plant	1					1.000	0.234*	-0.254*	0.135	0.063	0.893**
	2					1.000	0.056	-0.032	0.598	0.164	0.918**
	3					1.000	0.219	-0.217	-0.066	0.085	0.968**
	4					1.000	0.440*	-0.022	-0.201	-0.202	0.934**
No. of seeds per pod	1						1.000	0.108	-0.242*	0.030	0.266*
	2						1.000	0.091	-0.233	0.030	0.020
	3						1.000	-0.068	-0.163	-0.070	0.190
	4						1.000	0.107	-0.324	0.099	0.479*
100-seed weight (g)	1							1.000	-0.630**	0.231*	0.149
	2							1.000	-0.606	0.097	0.326
	3							1.000	-0.196	-0.144	0.010
	4							1.000	-0.721**	0.262	0.262
Seed protein content (%)	1								1.000	-0.260*	0.131
	2								1.000	-0.334	0.293
	3								1.000	-0.045	-0.115
	4								1.000	-0.078	-0.400
Crude fibre content (%)	1									1.000	0.061
	2									1.000	0.260
	3									1.000	0.044
	4									1.000	-0.126
Seed yield per plant (g)	1										1.000
	2										1.000
	3										1.000
	4										1.000

1= Phenotypic correlation matrix for the cross in general.
2= Phenotypic correlation matrix for the white flowered plants.
3= Phenotypic correlation matrix for the pink flowered plants.
4= Phenotypic correlation matrix for the blue flowered plants.

* Significant at 5% level
** Significant at 1% level

plants in the F_2 generation of the cross RS 11 x T 39-1 as a whole and within white, pink and blue flowered plants. The results are presented in Table 5.

4.4.2.1 Plant height

Plant height showed highly significant positive correlations with number of primary branches per plant (0.379**) and number of secondary branches per plant (0.349**). It showed significant positive correlations with number of pods per plant (0.261*), number of seeds per plant (0.250*) and seed yield per plant (0.221*). It had highly significant negative correlation with crude fibre content (-280**) in this cross.

This character showed significant positive correlation with only seed protein content (0.766*) in white flowered plants. With all other characters it showed non-significant correlations. In pink flowered plants, it had significant positive correlations with number of primary branches per plant (0.304*) and 100-seed weight (0.269*), and negative correlation with crude fibre content (-0.266*).

This character exhibited significant positive correlations with number of primary branches per plant (0.433*), number of secondary branches per plant (0.413*), number of seeds per plant (0.439*) and seed yield per plant (0.466*) in blue flowered plants. Plant height showed maximum positive correlation with seed protein content in white flowered plants (0.766*).

4.4.2.2 Number of primary branches per plant

Number of primary branches per plant was highly significantly and positively correlated with plant height (0.379**), number of secondary branches per plant (0.723**), number of pods per plant (0.335**), number of seeds per plant (0.323**) and seed yield per plant (0.284**) in this cross, while it was highly significantly and positively correlated with only number of secondary branches (0.804**) in white flowered plants. Number of primary branches per plant was not correlated with plant height and was non-significantly correlated with all other characters in this white flowered plants.

Among the pink flowered plants, this character was highly significantly and positively correlated with number of secondary branches per plant (0.674**), number of pods per plant (0.396**), number of seeds per plant (0.414**) and seed yield per plant (0.455**). It was significantly and positively correlated with plant height (0.304*).

In blue flowered plants, it was highly significantly and positively correlated with number of secondary branches per plant (0.721**) and significantly and positively correlated with plant height (0.433*). Number of primary branches per plant was most highly correlated with number of secondary branches (0.804**) in white flowered plants.

4.4.2.3 Number of secondary branches per plant

In this cross, highly significant and positive association of number of secondary branches per plant was seen with plant height (0.349**), number of primary branches per plant (0.723**), number of pods per plant (0.519**), number of seeds per plant (0.476**) and seed

yield per plant (0.388**). Significant negative association of this character was seen with crude fibre content (-0.234*).

In white flowered plants, highly significant and positive association was noted only with number of primary branches per plant (0.804**), while in the pink flowered plants this character was observed to have highly significant and positive association with number of primary branches per plant (0.674**), number of pods per plant (0.426**), number of seeds per plant (0.404**) and seed yield per plant (0.441**). Significant negative association of this character was seen with crude fibre content (-0.276).

Among the blue flowered plants, highly significant and positive association of this character was seen with number of primary branches per plant (0.721**), number of pods per plant (0.663**) and number of seeds per plant (0.561**). Significant positive association of this character was observed with plant height (0.413*) and seed yield per plant (0.434*). Number of secondary branches per plant was most highly associated with number of primary branches per plant (0.804**) in white flowered plants.

4.4.2.4 Number of pods per plant

In the cross in general, highly significant and positive correlations were seen between number of pods per plant and number of primary branches per plant (0.335**), number of secondary branches per plant (0.519**), number of seeds per plant (0.883**) and seed yield per plant (0.741**). Significant positive correlations were seen between number of pods per

plant and plant height (0.261*) and seed protein content (0.248*). Highly significant negative correlation of this character was observed with 100-seed weight (-0.343**).

Among the white flowered plants, highly significant positive correlations of this character were seen with number of seeds per plant (0.925**) and seed yield per plant (0.879**). In pink flowered plants, this character was found to have highly significant and positive correlations with number of primary branches per plant (0.396**), number of secondary branches per plant (0.426**), number of seeds per plant (0.894**) and seed yield per plant (0.872**).

Highly significant and positive correlations of this character were seen with number of secondary branches per plant (0.663**), number of seeds per plant (0.843**) and seed yield per plant (0.706**) in blue flowered plants.

Number of pods per plant showed maximum correlation with number of seeds per plant in white flowered plants (0.925**).

4.4.2.5 Number of seeds per plant

Number of seeds per plant exhibited highly significant positive association with number of primary branches per plant (0.323**), number of secondary branches per plant (0.476**), number of pods per plant (0.883**) and seed yield per plant (0.893**) in this cross. It showed significant positive association with plant height (0.250*) and number of seeds per pod (0.234*). It had significant negative association with 100-seed weight (-0.254*).

Within the white flowered plants, it showed highly significant positive association with number of pods per plant (0.925**) and seed yield per plant (0.918**). In pink flowered plants, it reported highly significant positive association with number of primary branches per plant (0.414**), number of secondary branches per plant (0.404**), number of pods per plant (0.894**) and seed yield per plant (0.968**).

In blue flowered plants, it resulted in highly significant positive association with number of secondary branches per plant (0.561**), number of pods per plant (0.843**) and seed yield per plant (0.934**), and significant positive association with plant height (0.439*) and number of seeds per pod (0.440*). Number of seeds per plant had maximum association with seed yield per plant in pink flowered plants (0.968**).

4.4.2.6 Number of seeds per pod

The correlations of number of seeds per pod were significant and positive with number of seeds per plant (0.234*) and seed yield per plant (0.266*), while it was negative and significant with seed protein content (-0.242*) in this cross.

In white and pink flowered plants, number of seeds per pod had non-significant correlations with all other characters, while in the blue flowered plants it showed significant positive correlations with number of seeds per plant (0.440*) and seed yield per plant (0.479*). Number of seeds per pod exhibited high correlation with seed yield per plant in blue flowered plants (0.479*).

4.4.2.7 100-seed weight

100-seed weight showed highly significant negative correlations with number of pods per plant (-0.343**) and seed protein content (-0.630**), and significant negative correlation with number of seeds per plant (-0.254*) in this cross. It had significant positive correlation with crude fibre content (0.231*).

In white flowered plants, it exhibited no significant correlations with any of the other characters, while in pink flowered plants it had significant positive correlation with plant height (0.269*). In blue flowered plants, it showed highly significant negative correlation with seed protein content (-0.721**).

4.4.2.8 Seed protein content

In this cross, relationship of seed protein content with number of pods per plant (0.248*) was significant and positive. Relationship was highly significant and negative with 100-seed weight (-0.630**). Significant and negative relationship was recorded with number of seeds per pod (-0.242*) and crude fibre content (-0.260*).

In white flowered plants, relationship of seed protein content was significant and positive with only plant height (0.766*) and non-significant with other characters. In pink flowered plants relationship was non-significant with all the other characters, whereas in the blue flowered plants, relationship of this character was highly significant and negative with 100-seed weight (-0.721**).

4.4.2.9 Crude fibre content

Crude fibre content had highly significant negative association with plant height (-0.280**) and significant negative association with number of secondary branches per plant (-0.234*) and seed protein content (-0.260*). It showed significant positive association with 100-seed weight (0.231*) in this cross.

It exhibited non-significant association with all the other characters studied in plants having white and blue flowers, whereas it had significant negative association with plant height (-0.266*) and number of secondary branches (-0.276*) in plants having pink flowers.

4.4.2.10 Seed yield per plant

The seed yield per plant was highly significantly and positively correlated with number of primary branches per plant (0.284**), number of secondary branches per plant (0.388**), number of pods per plant (0.741**) and number of seeds per plant (0.893**). It was significantly and positively correlated with plant height (0.221*) and number of seeds per pod (0.266*) in this cross.

In white flowered plants, it was correlated highly significantly and positively with number of pods per plant (0.879**) and number of seeds per plant (0.918**). It was positively and highly significantly correlated with number of primary branches per plant (0.455**), number of secondary branches per plant (0.441**), number of pods per plant (0.872**) and number of seeds per plant (0.968**) in the pink flowered plants.

In blue flowered plants, it was correlated positively and highly significantly with number of pods per plant (0.706**) and number of seeds per plant (0.934**). It was correlated significantly and positively with plant height (0.466*), number of secondary branches per plant (0.434*) and number of seeds per pod (0.479*). Maximum correlation of seed yield was seen with number of seeds per plant (0.968*) in the pink flowered plants.

4.5 Variability for characters

Differences of means among the three parents P 9623, RS 11 and T 39-1 and between the two crosses P 9623 x T 39-1 and RS 11 x T 39-1 at F_2 generation were determined for various qualitative and quantitative characters studied. The ranges were also determined for various quantitative characters studied. The results of the investigation are presented hereunder.

4.5.1 Among parents

Differences of means among the three parents P 9623, RS 11 and T 39-1 were worked out for yield and yield contributing characters, and qualitative characters like seed coat colour and seed type. Ranges were determined for yield and yield contributing characters.

4.5.1.1 Qualitative characters

P 9623 parent has a seed coat colour of salmon white with kabuli type of seed. In the parent RS 11 the seed is of desi type with yellow brown seed coat colour, while in the third parent T 39-1, the seed is of intermediate type with gray seed coat colour. Thus, the seed coat colour and seed type were significantly different in the three parents studied (Plates 5 and 6).

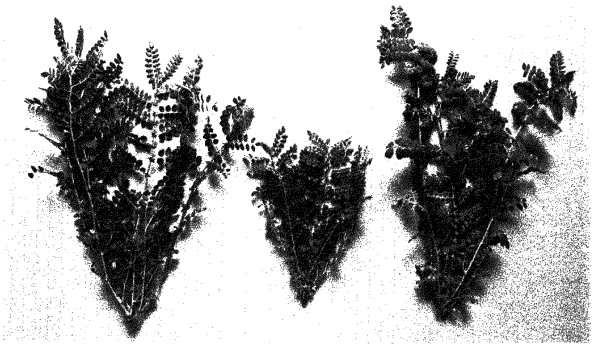


Plate 3 : Variation in growth habit of the parents T 39-1, RS 11 and P 9623.

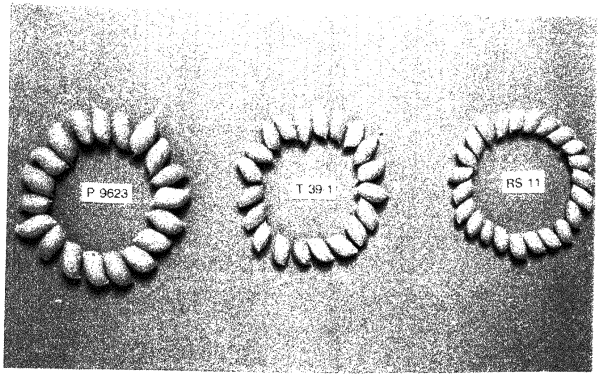
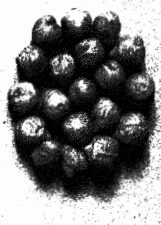
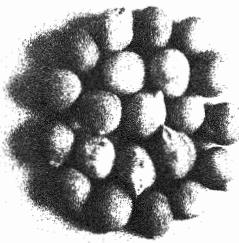


Plate 4 : Variation in pod size of the parents P 9623, T 39-1 and RS 11.

P 9623



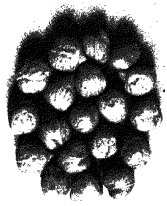
T 39-1



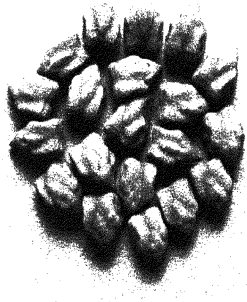
F_1 (P 9623 x T 39-1)

Plate 5 : Variation in seed characters of the parents P 9623 and T 39-1 and their F_1.

RS 11



T 39-1



F_1 (RS 11 x T 39-1)

Plate 6 : Variation in seed characters of the parents RS 11 and T 39-1 and their F_1

Table 6 : Means and ranges for 10 characters for the parents P 9623, RS 11 and T 39-1, Rabi 1997/98.

Character	P 9623		RS 11		T 39-1	
	Mean ± S.E.	Range	Mean ± S.E.	Range	Mean ± S.E.	Range
Plant height (cm)	54.80 ± 4.705	41.00 - 69.00	44.56 ± 1.168	40.00 - 50.00	56.70 ± 0.895	53.00 - 62.00
No. of primary branches per plant	4.20 ± 0.860	2.00 - 7.00	2.78 ± 0.278	2.00 - 4.00	5.10 ± 0.526	3.00 - 8.00
No. of secondary branches per plant	8.80 ± 1.655	5.00 - 14.00	5.89 ± 0.484	4.00 - 8.00	10.20 ± 1.104	5.00 - 16.00
No. of pods per plant	44.40 ± 5.278	31.00 - 60.00	105.44 ± 27.49	41.00 - 312.00	95.20 ± 3.999	80.00 - 117.00
No. of seeds per plant	42.80 ± 4.934	29.00 - 56.00	122.11 ± 34.604	43.00 - 378.00	92.70 ± 7.315	68.00 - 138.00
No. of seeds per pod	0.97 ± 0.013	0.90 - 1.00	1.11 ± 0.044	0.80 - 1.20	0.96 ± 0.039	0.82 - 1.18
100 - seed weight (g)	35.69 ± 1.303	31.80 - 39.70	14.65 ± 0.310	13.50 - 15.80	10.92 ± 0.514	8.30 - 12.80
Seed protein content (%)	24.32 ± 0.554	23.10 - 26.30	22.47 ± 0.519	20.40 - 24.90	30.24 ± 0.440	27.70 - 31.80
Crude fibre content (%)	3.63 ± 0.256	3.02 - 4.49	9.78 ± 0.157	9.10 - 10.30	4.93 ± 0.070	4.60 - 5.20
Seed yield per plant (g)	15.28 ± 1.855	10.30 - 20.60	17.32 ± 4.558	6.80 - 50.90	9.80 ± 0.298	8.70 - 11.50

Table 7 : Test of significance of means for 10 characters among the parents P 9623, RS 11 and T 39-1, *Rabi* 1997/98.

Character	t value for P 9623 and RS 11	Probability value	t value for P 9623 and T 39-1	Probability value	t value for RS 11 and T 39-1	Probability value
Plant height (cm)	3.455	0.00427**	0.675	0.51040	11.748	0.00000**
No. of primary branches per plant	2.535	0.02490*	1.371	0.19200	5.435	0.00004**
No. of secondary branches per plant	2.739	0.01689*	1.066	0.30460	4.969	0.00010**
No. of pods per plant	2.740	0.01687*	11.374	0.00000**	0.533	0.60063
No. of seeds per plant	2.843	0.01385*	7.541	0.00000**	1.205	0.24369
No. of seeds per pod	3.876	0.00191**	0.306	0.76440	3.619	0.00196**
100-seed weight (g)	25.740	0.00000**	28.754	0.00000**	8.682	0.00000**
Seed protein content (%)	3.479	0.00408**	9.718	0.00000**	13.329	0.00000**
Crude fibre content (%)	31.042	0.00000**	8.204	0.00000**	40.622	0.00000**
Seed yield per plant (g)	0.534	0.60224	4.990	0.00020**	2.391	0.02791*

4.5.1.2 Yield contributing characters and yield

The results showing the differences among the three parents for yield and yield related characters are presented in Tables 6 and 7, and Plates 3, 4, 5 and 6.

4.5.1.2.1 Plant height

The mean values of plant height for P 9623, RS 11 and T 39-1 were 54.80 cm, 44.56 cm and 56.70 cm respectively. The range was 41.00 - 69.00 cm for P 9623, 40.00 - 50.00 cm for RS 11 and 53.00 - 62.00 cm for T 39-1. Highly significant differences for the plant height character were observed between P 9623 and RS 11, and RS 11 and T 39-1. No significant difference was found between P 9623 and T 39-1. From this study, it was observed that P 9623 and T 39-1 had taller plant height than RS 11.

4.5.1.2.2 Number of primary branches per plant

The number of primary branches per plant ranged from 2.00 - 7.00 in P 9623, 2.00 - 4.00 in RS 11 and 3.00 - 8.00 in T 39-1. The mean values for P 9623, RS 11 and T 39-1 were 4.20, 2.78 and 5.10 respectively. Comparison studies showed highly significant difference between RS 11 and T 39-1, and significant difference between P 9623 and RS 11. This character showed no significant difference between P 9623 and T 39-1 and these two parents recorded higher number of primary branches per plant than RS 11.

4.5.1.2.3 Number of secondary branches per plant

The number of secondary branches per plant showed a mean of 8.80 with a range of

5.00 - 14.00 in P 9623. In RS 11 mean was 5.89 with a range of 4.00 - 8.00, while in T 39-1 mean was 10.20 with a range of 5.00 - 16.00. Comparison studies showed highly significant difference between RS 11 and T 39-1. Significant difference was observed between P 9623 and RS 11. P 9623 and T 39-1 showed no significant difference. P 9623 and T 39-1 showed more number of secondary branches per plant than RS 11.

4.5.1.2.4 Number of pods per plant

This character showed a range of 31.00 - 60.00 with a mean of 44.40 in P 9623, a range of 41.00 - 312.00 with a mean of 105.44 in RS 11 and a range of 80.00 - 117.00 with a mean of 95.20 in T 39-1. P 9623 and T 39-1 noted highly significant difference, while P 9623 and RS 11 noted significant difference for this character. There was no significant difference between RS 11 and T 39-1 and both had more number of pods per plant than P 9623.

4.5.1.2.5 Number of seeds per plant

The number of seeds per plant had a mean of 42.80 with a range of 29.00 - 56.00 in P 9623, a mean of 122.11 with a range of 43.00 - 378.00 in RS 11 and a mean of 92.70 with a range of 68.00 - 138.00 in T 39-1. P 9623 and RS 11 recorded significant difference for this character, while P 9623 and T 39-1 recorded highly significant difference. RS 11 and T 39-1 reported no significant difference. RS 11 and T 39-1 had more number of seeds per plant followed by P 9623.

4.5.1.2.6 Number of seeds per pod

The number of seeds per pod ranged from 0.90 - 1.00 with a mean value of 0.97 in P 9623.

In RS 11 it ranged from 0.80 - 1.20 with a mean value of 1.11, whereas in T 39-1 it ranged from 0.82 - 1.18 with a mean value of 0.96. Highly significant differences were found between P 9623 and RS 11, and RS 11 and T 39-1. No significant difference was found between P 9623 and T 39-1. The number of seeds per pod was highest in RS 11 followed by P 9623 and T 39-1.

4.5.1.2.7 100-seed weight

In P 9623, 100-seed weight showed a mean of 35.69 g with a range of 31.80 - 39.70 g, while it showed a mean of 14.65 g with a range of 13.50 - 15.80 g in RS 11. In T 39-1 it showed a mean of 10.92 g with a range of 8.30 - 12.80 g. Comparison studies indicated highly significant differences among all the three parents. P 9623 recorded highest 100-seed weight followed by RS 11 and then by T 39-1.

4.5.1.2.8 Seed protein content

The mean values of seed protein content were 24.32%, 22.47% and 30.24% respectively in P 9623, RS 11 and T 39-1. It ranged from 23.10 - 26.30% in P 9623, 20.40 - 24.90% in RS 11 and 27.70 - 31.80% in T 39-1. On comparison highly significant differences were found for this character among the three parents. Highest seed protein content was observed in T 39-1 followed by P 9623 and then by RS 11.

4.5.1.2.9 Crude fibre content

This character recorded a range of 3.02 - 4.49% with a mean of 3.63% in P 9623, a range of 9.10 - 10.30% with a mean of 9.78% in RS 11 and a range of 4.60 - 5.20% with a mean of

4.93% in T 39-1. All the parents studied reported highly significant differences for this character among themselves. RS 11 had higher crude fibre content than the other two parents. T 39-1 had higher crude fibre content than that of P 9623.

4.5.1.2.10 Seed yield per plant

Seed yield per plant was found to have a mean value of 15.28 g with a range of 10.30 - 20.60 g in P 9623, a mean value of 17.32 g with a range of 6.80 - 50.90 g in RS 11 and a mean value of 9.80 g with a range of 8.70 - 11.50 g in T 39-1. Highly significant difference was found between P 9623 and T 39-1, and significant difference was noted between RS 11 and T 39-1, while no significant difference was found between P 9623 and RS 11. RS 11 and P 9623 were observed to have higher seed yield per plant than T 39-1.

From the present investigation it could be observed that P 9623 had taller plant height, more number of primary and secondary branches and higher seed yield per plant. It had highest 100-seed weight. RS 11 had more number of pods and seeds per plant, highest number of seeds per pod and crude fibre content and showed higher seed yield per plant. While T 39-1 showed taller plant height, more number of primary and secondary branches, and pods and seeds per plant. T 39-1 showed highest seed protein content.

4.5.2 Between crosses

Differences between the two crosses for qualitative characters like seed coat colour and seed type, and seed yield and yield contributing traits were worked out for F_2 generations. Ranges were determined for yield and yield contributing traits.

Table 8 : Means and ranges for 10 characters for F_2 generation of two chickpea crosses, *Rabi* 1997/98.

Character	P 9623 x T 39-1		RS 11 x T 39-1		t value	Probability value
	Mean ± S.E.	Range	Mean ± S.E.	Range		
Plant height (cm)	53.75 ± 0.562	42.00 - 70.00	51.76 ± 0.574	40.00 - 64.00	3.508	0.0006**
No. of primary branches per plant	4.62 ± 0.141	2.00 - 10.00	4.46 ± 0.157	2.00 - 9.00	1.107	0.2697
No. of secondary branches per plant	10.81 ± 0.394	4.00 - 22.00	10.21 ± 0.382	4.00 - 20.00	0.202	0.8402
No. of pods per plant	58.69 ± 3.763	10.00 - 301.00	77.99 ± 4.504	10.00 - 244.00	4.705	0.0000**
No. of seeds per plant	52.39 ± 3.701	10.00 - 305.00	84.27 ± 5.025	13.00 - 249.00	7.370	0.0000**
No. of seeds per pod	0.91 ± 0.025	0.40 - 2.00	1.11 ± 0.027	0.60 - 2.00	7.725	0.0000**
100-seed weight (g)	25.56 ± 0.618	11.70 - 46.90	14.95 ± 0.352	7.70 - 22.30	20.429	0.0000**
Seed protein content (%)	25.94 ± 0.182	21.40-30.50	24.32 ± 0.224	20.50 - 30.10	8.046	0.0000**
Crude fibre content (%)	4.19 ± 0.083	2.52 - 6.50	8.48 ± 0.125	5.20 - 11.60	41.498	0.0000**
Seed yield per plant (g)	12.80 ± 0.891	2.60 - 73.50	12.26± 0.745	1.60 - 41.60	0.646	0.5187

4.5.2.1 Qualitative characters

In the cross P 9623 x T 39-1, 117 plants were studied in F_2 generation. Two types of seed were observed namely kabuli and intermediate. Seed coat colours observed were salmon white, light brown, gray, brown and blackish brown (Appendix A).

In the cross RS 11 x T 39-1, 90 plants of the F_2 generation were studied. In this also two types of seed namely desi and intermediate were observed. Seed coat colour varied from yellow brown, orange brown, light brown, gray, brown to dark brown (Appendix B).

4.5.2.2 Yield and yield contributing characters

The results showing difference between the two crosses are presented in Table 8.

4.5.2.2.1 Plant height

Plant height ranged from 42.00 to 70.00 cm with a mean of 53.75 cm in P 9623 x T 39-1 cross, while it ranged from 40.00 to 64.00 cm with a mean of 51.76 cm in RS 11 x T 39-1 cross. The crosses showed highly significant difference for this character. P 9623 x T 39-1 had taller plant height than the other cross RS 11 x T 39-1.

4.5.2.2.2 Number of primary branches per plant

The range of number of primary branches per plant in the cross P 9623 x T 39-1 was 2.00 - 10.00, while it was 2.00 - 9.00 in the cross RS 11 x T 39-1. The mean value of this character was 4.62 in the cross P 9623 x T 39-1 and 4.46 in the cross RS 11 x T 39-1. On comparison no significant difference was found for this character.

4.5.2.2.3 Number of secondary branches per plant

The mean value of number of secondary branches per plant in the cross P 9623 x T 39-1 was 10.81 with a range of 4.00 - 22.00, whereas in the cross RS 11 x T 39-1 the mean value was 10.21 with a range of 4.00 - 20.00. The difference between the crosses for this trait was not significant.

4.5.2.2.4 Number of pods per plant

The number of pods per plant varied from 10.00 - 301.00 in the cross P 9623 x T 39-1 with a mean value of 58.69, while it varied from 10.00 - 244.00 in the cross RS 11 x T 39-1 with a mean value of 77.99. The two crosses noted highly significant difference for this character and the cross RS 11 x T 39-1 showed more number of pods per plant than P 9623 x T 39-1 cross. This difference may have occurred because of pod size variation between the crosses.

4.5.2.2.5 Number of seeds per plant

The number of seeds per plant was observed to show a range of 10.00 - 305.00 and 13.00 - 249.00 in the crosses P 9623 x T 39-1 and RS 11 x T 39-1 respectively. The mean value was 52.39 in the cross P 9623 x T 39-1 and 84.27 in the cross RS 11 x T 39-1. Highly significant difference was observed between the crosses for this character. RS 11 x T 39-1 cross showed more number of seeds per plant than the other cross P 9623 x T 39-1. Differences in seed size might have effected this character resulting in more number of seeds per plant in the cross RS 11 x T 39-1 having lesser seed size.

4.5.2.2.6 Number of seeds per pod

The number of seeds per pod noted a range of 0.40 - 2.00 with a mean value of 0.91 in the cross P 9623 x T 39-1 and a range of 0.60 - 2.00 with a mean value of 1.11 in the cross RS 11 x T 39-1. Comparison in both the crosses indicated highly significant difference for this character and the cross RS 11 x T 39-1 showed more number of seeds per pod than the cross P 9623 x T 39-1. Seed size might have effected this character resulting in more number of seeds per pod in the cross RS 11 x T 39-1 having lesser seed size.

4.5.2.2.7 100-seed weight

In the cross P 9623 x T 39-1, 100-seed weight ranged from 11.70 - 46.90 g with a mean value of 25.56 g, whereas it ranged from 7.70 - 22.30 g with a mean value of 14.95 g in the cross RS 11 x T 39-1. This character exhibited highly significant difference between the crosses. The cross P 9623 x T 39-1 recorded heavier 100-seed weight than the other cross. Within each cross 100-seed weight varied in the three flowered types. In both the crosses, it was more in pink and white flowered plants and lowest in blue flowered plants (Figure 7).

4.5.2.2.8 Seed protein content

Seed protein content recorded a range of 21.40 - 30.50% with a mean of 25.94% in the cross P 9623 x T 39-1 and a range of 20.50 - 30.10% with a mean of 24.32% in the cross RS 11 x T 39-1. On comparison, the crosses noted highly significant difference and the cross P 9623 x T 39-1 had more mean seed protein content than the other cross. In both the crosses, differences were found among the three flowered plants for this character. It was highest in blue flowered plants followed by white and pink flowered plants (Figure 8).

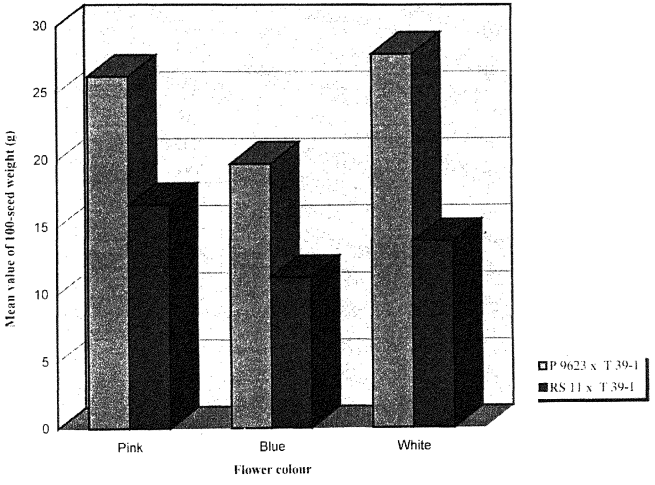


Figure 7 : Mean value of 100-seed weight for pink, blue and white flowered plants in F_2 generations of the chickpea crosses P 9623 x T 39-1 and RS 11 x T 39-1.

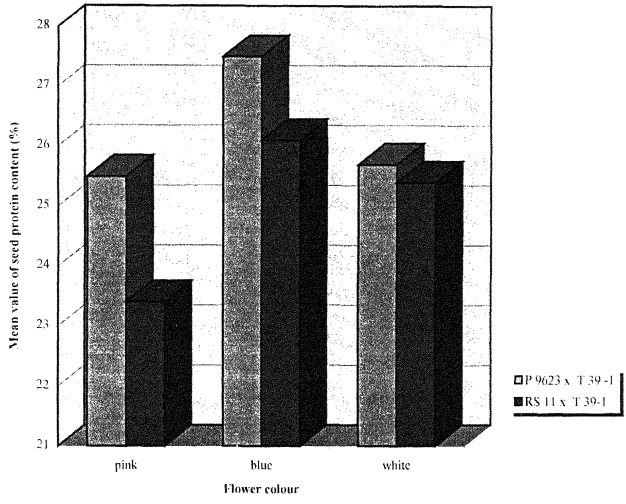


Figure 8 : Mean seed protein content for pink, blue and white flowered plants in F_2 generations of the chickpea crosses P 9623 x T 39-1 and RS 11 x T 39-1.

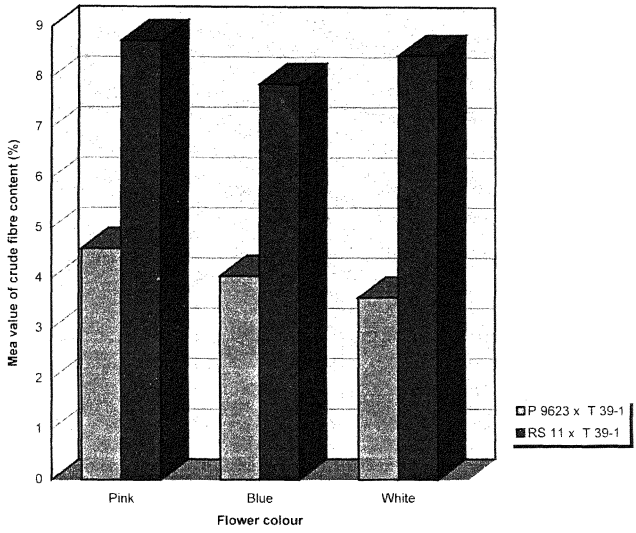


Figure 9 : Mean crude fibre content for pink, blue and white flowered plants in F_2 generations of the chickpea crosses P 9623 x T 39-1 and RS 11 x T 39-1.

4.5.2.2.9 Crude fibre content

Crude fibre content ranged from 2.52 - 6.50% with a mean value of 4.19% in the cross P 9623 x T 39-1, whereas it ranged from 5.20 - 11.60% with a mean value of 8.48% in the cross RS 11 x T 39-1. Highly significant difference was found between the crosses. Crude fibre content was more in the cross RS 11 x T 39-1 than in the other cross. This character also showed differences among the three flowered plants in both the crosses. It was highest in pink flowered plants in both the crosses (Figure 9).

4.5.2.2.10 Seed yield per plant

Seed yield per plant recorded a mean value of 12.80 g with a range of 2.60 - 73.50 g in the cross P 9623 x T 39-1, while it recorded a mean of 12.26 g with a range of 1.60 - 41.60 g in the other cross RS 11 x T 39-1. There was no significant difference between both the crosses for this character.

From the differences studied on various characters, the cross RS 11 x T 39-1 had more number of pods per plant, seeds per plant, seeds per pod and crude fibre content. The other cross P 9623 x T 39-1 had taller plant height, heavier 100-seed weight and more seed protein content than the cross RS 11 x T 39-1.

4.6 Heterosis

The magnitude of mid parent and better parent heterosis for yield, its components, seed protein and crude fibre content for the two chickpea crosses is presented in Table 9. Characters of the two F_1s are shown in Plates 5, 6, 7 and 8.

F_1 (RS 11 x T 39-1) F_1 (P 9623 x T 39-1)

Plate 7 : Variation in growth habit of F_1s of the crosses RS 11 x T 39-1 and P 9623 x T 39-1.

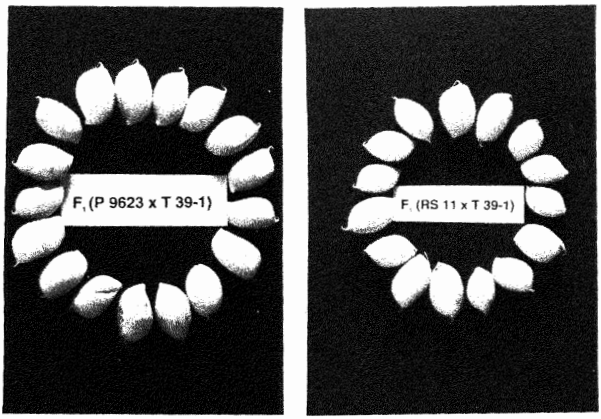


Plate 8 : Variation in pod size of F_1s of the crosses P 9623 x T 39-1 and RS 11 x T 39-1

Table 9 : Mid parent and better parent heterosis for 10 characters studied in the F_1s of two crosses of chickpea, *Rabi* 1997/98.

Character	P 9623 x T 39-1			RS 11 x T 39-1		
	Mean of F_1	Mid parent heterosis (%)	Better parent heterosis (%)	Mean of F_1	Mid parent heterosis (%)	Better parent heterosis (%)
Plant height (cm)	55.38	-0.66	-2.33	56.40	11.40	-0.53
Number of primary branches per plant	5.00	7.53	-1.96	5.00	29.44	-1.96
Number of secondary branches per plant	10.00	5.26	-1.96	10.00	26.71	-1.96
Number of pods per plant	81.00	16.05	-14.92	107.10	6.78	1.61
Number of seeds per plant	88.00	29.89	-5.07	123.60	15.08	1.23
Number of seeds per pod	1.09	12.37	12.37	1.10	5.77	-0.90
100-seed weight (g)	23.77	1.97	-33.40	16.24	26.97	10.85
Seed protein content (%)	23.51	-13.82	-22.26	21.72	-17.60	-28.18
Crude fibre content (%)	5.23	22.20	6.09	9.26	25.82	-5.32
Seed yield per plant (g)	20.92	66.83	36.91	20.07	48.01	15.88

4.6.1 Plant height

In P 9623 x T 39-1 cross, mid parent heterosis (-0.66%) and better parent heterosis (-2.33%) for the plant height were low and negative, while in the other cross RS 11 x T 39-1 mid parent heterosis was positive (11.40%) but better parent heterosis was negative (-0.53%). Heterosis was higher in the cross RS 11 x T 39-1 than the other cross.

4.6.2 Number of primary branches per plant

Mid parent heterosis for number of primary branches per plant in the cross P 9623 x T 39-1 was positive (7.53%), while better parent heterosis was negative (-1.96%). Mid parent heterosis was positive (29.44%) and better parent heterosis was negative (-1.96%) in the cross RS 11 x T 39-1. Mid parent heterosis was higher in the cross RS 11 x T 39-1 than in the other cross for this character.

4.6.3 Number of secondary branches per plant

Positive mid parent heterosis was observed for number of secondary branches per plant in both the crosses P 9623 x T 39-1 and RS 11 x T 39-1 (5.26 and 26.71% respectively). However, better parent heterosis was negative in both the crosses (-1.96% for both the crosses). Mid parent heterosis for this character was higher in the cross RS 11 x T 39-1 than the other cross P 9623 x T 39-1.

4.6.4 Number of pods per plant

Number of pods per plant showed positive mid parent heterosis (16.05%) and negative better parent heterosis (-14.92%) in the cross P 9623 x T 39-1. This character showed

positive mid parent heterosis (6.78%) and better parent heterosis (1.61%) in the other cross RS 11 x T 39-1. Mid parent heterosis observed was low in both the crosses but comparatively higher in the cross P 9623 x T 39-1.

4.6.5 Number of seeds per plant

Positive mid parent heterosis (29.89%) and negative better parent heterosis (-5.07%) were observed for number of seeds per plant in the cross P 9623 x T 39-1, while positive mid parent heterosis (15.08%) and better parent heterosis (1.23%) were observed for this character in the cross RS 11 x T 39-1. Mid parent heterosis was higher in P 9623 x T 39-1 cross than the other cross RS 11 x T 39-1.

4.6.6 Number of seeds per pod

Number of seeds per pod exhibited positive mid parent heterosis (12.37%) and better parent heterosis (12.37%) in the cross P 9623 x T 39-1. In the cross RS 11 x T 39-1, this character had positive mid parent heterosis (5.77%) and negative better parent heterosis (-0.90%). The F_1 of the cross P 9623 x T 39-1 showed greater heterosis compared to the other cross RS 11 x T 39-1 although the heterosis values were low.

4.6.7 100-seed weight

In the cross P 9623 x T 39-1 mid parent heterosis was positive (1.97%) and better parent heterosis was negative (-33.40%) for 100-seed weight, while mid parent heterosis (26.97%) and better parent heterosis (10.85%) were positive in the cross RS 11 x T 39-1. Heterosis was comparatively higher in the cross RS 11 x T 39-1.

4.6.8 Seed protein content

Seed protein content exhibited negative mid parent heterosis (-13.82% and -17.60%) and better parent heterosis (-22.26% and -28.18%) in both the crosses P 9623 x T 39-1 and RS 11 x T 39-1 respectively.

4.6.9 Crude fibre content

Crude fibre content showed positive mid parent heterosis (22.20%) and better parent heterosis (6.09%) in the cross P 9623 x T 39-1. In the other cross RS 11 x T 39-1, this character showed positive mid parent heterosis (25.82%) but negative better parent heterosis (-5.32%). Mid parent heterosis for this character was higher in the cross RS 11 x T 39-1.

4.6.10 Seed yield per plant

Positive values of mid parent heterosis (66.83% and 48.01%) and better parent heterosis (36.91% and 15.88%) were noted in both the crosses P 9623 x T 39-1 and RS 11 x T 39-1 respectively. Mid parent and better parent heterosis were comparatively higher in the cross P 9623 x T 39-1 than in the other cross.

Heterosis differed from character to character and cross to cross. In the cross P 9623 x T 39-1 mid parent heterosis was high for seed yield per plant (66.83%) and low for seed protein content (-13.82%), while better parent heterosis was high for seed yield per plant (36.91%) and low for 100-seed weight (-33.40%). In the cross RS 11 x T 39-1 mid parent and better parent heterosis were high for seed yield per plant (48.01 and 15.88%, respectively) and low for seed protein content (-17.60 and -28.18%, respectively).

DISCUSSION

CHAPTER V

DISCUSSION

Genetic studies on flower colour, seed protein content, crude fibre content and some important yield contributing characters and yield were conducted on two selected crosses of chickpea. The material for this study consisted of three parents P 9623, RS 11 and T 39-1 and two crosses namely P 9623 x T 39-1 and RS 11 x T 39-1 at F_1 and F_2 generations. The results of the present investigation are discussed under the following headings:

5.1 Inheritance of flower colour

5.2 Inheritance of seed protein content

5.3 Inheritance of crude fibre content

5.4 Correlation coefficients

5.5 Variability for characters

5.6 Heterosis

5.1 Inheritance of flower colour

In chickpea, three distinct flower colours are identified namely pink, blue and white. Most of the varieties are pink flowered types. Varieties with white flowers are few and those with blue flowers are rare (Pundir *et al.*, 1988).

Flower and seed coat colours are tightly linked (Bhapkar and Patil, 1963; D'Cruz and Tendulkar, 1970; Jagtap *et al.*, 1973 and Pawar and Patil, 1982 and 1983). It was

observed that white flowered parent, P 9623 had salmon white coloured seeds but the other white flowered parent, RS 11 had yellow brown coloured seeds instead of salmon white or cream coloured seeds indicating breakdown of linkage between flower colour and seed coat colour. The blue flowered parent, T 39-1 had higher protein content than either of the other two parents. It was earlier observed that a blue flowered parent, T-1-A had higher seed protein percentage and smaller seed size than the pink flowered parent, Annigeri and linkage existed between the three characters (Kumar *et al.*, 1982). To the best of our knowledge the blue flowered parent, T 39-1 used in the present study was not used in any of the earlier studies. Therefore, to study the inheritance of flower colour, T 39-1 was used as a common male parent in two crosses with white flowered female parents, P 9623 and RS 11 in the present investigation.

In both the crosses between white flowered parents and blue flowered parent, the F_1s were pink. This indicated interaction between the genes for white and blue flower colours resulting in the formation of pink flower in the F_1s. This suggested the involvement of more than one gene in governing the flower colour. This varies with the results of Pimplikar (1943), Khan *et al.* (1950), Bhapkar and Patil (1963), Patil (1964), Athwal and Brar (1967), Patil (1967), Khosh-Khui and Niknejad (1971), Mian (1971), Jagtap *et al.* (1973), More and D'Cruz (1976), Nayeem *et al.* (1977), Reddy and Nayeem (1978), Yadav *et al.* (1978), Kumar *et al.* (1982), Pawar and Patil (1982 and 1983), Kidambi *et al.* (1988), Singh *et al.* (1988), Gil and Cubero (1993) and Pundir and Reddy (1997) who proposed monogenic inheritance model.

In the present study, the F_2 segregation ratio of 9 pink : 3 blue : 4 white flower colours in both the crosses indicated supplementary type of gene action and digenic control of this character. Digenic inheritance model was proposed by Khan and Akhtar (1934), Pal (1934), Kadam *et al.* (1941), More and D'Cruz (1970), Deshmukh *et al.* (1972), Patil and Deshmukh (1975), Reddy and Chopde (1977), Pawar and Patil (1979), Rao *et al.* (1980), Davis (1991) and Kumar (1997). According to this digenic model, assuming gene designations as proposed by Khan and Akhtar, a dominant factor B produced blue colour. A factor P gave pink colour in the presence of B, but by itself produced no colour. In the absence of B, the flowers were white, whether P was present or not indicating the epistatic action of "bb".

The different gene symbols given by different scientists, namely B, Bco, Lvco and Pco_a for blue colour and P, Sco, Wco and Pco_b showing supplementary gene action could represent the same loci as they were designated without conducting the allelic tests.

The segregation ratio of 9 pink : 3 blue : 4 white flowers in the F_2 generation of both the crosses was indicative of similar genetic constitution of the two white flowered parents P 9623 and RS 11. However, this was not the case, as the two white flowered parents produced a pink F_1 when crossed (Kumar, 1997) indicating different genetic constitutions. Hence, the digenic model of inheritance was not found to be appropriate.

Therefore, the trigenic model of inheritance of the flower colour is found to be more appropriate. This was earlier proposed by Ayyar and Balasubramanian (1936), D'Cruz and

Tendulkar (1970) and Phadnis (1976). Assuming Ayyar and Balasubramanian's model, the flower colour in the present study was controlled by three factors C, B and P. All the three factors together in dominant condition produced pink colour. The factor B imparted blue colour to the petals in association with C and pink on the combined presence of C and P. Thus, B and C complemented each other resulting in the appearance of blue colour, but individually giving white colour to the petals. Factor P showed supplementary action converting blue to pink colour, but without any effect by itself giving white colour to the petals when present singly or in combination with either C or B. The recessive alleles of all these together also gave white colour.

Therefore, the genetic constitution of the blue parent T 39-1 could be CCBBpp. Pink flower of F_1 would have the genetic constitution of C_B_P_. The pink colour in the F_1s suggested the genetic constitution of CCBbPp or CcBBPp, as segregation was seen for only two genes in the F_2 generation. The white flowered parents, P 9623 and RS 11 could have any of the six possible genotypes (for white flower colour) namely CCbbPP, CCbbpp, ccBBPP, ccBBpp, ccbbPP and ccbbpp, but the pink F_1s suggested only three possible genotypes namely CCbbPP, ccBBPP and ccbbPP. The absence of trihybrid ratio in the F_2 ruled out the possibility of ccbbPP. So, the most possible genotypes for P 9623 and RS 11 could be either ccBBPP or CCbbPP. From similar studies on flower colour in chickpea (Kumar, 1997) the genetic constitution for P 9623 was found to be CCbbPP. Therefore, the genetic constitution for RS 11 is ccBBPP.

The proposed genetic constitution of the three parents and their respective F_1s are:

P 9623 : CCbbPP (White)

RS 11 : ccBBPP (White)

T 39-1 : CCBBpp (Blue)

F_1 (P 9623 x T 39-1) : CCBbPp (Pink)

F_1 (RS 11 x T 39-1) : CcBBPp (Pink)

The gene symbols for the flower colour given by Ayyar and Balasubramanian (1936) i.e. P, C and B and D'Cruz and Tendulkar (1970) i.e. Pco_a, Pco_{b1} and Pco_{b2} could be the same. However no allelic tests were conducted by the latter workers.

Thus, in the present study flower colour was governed by three genes. The study confirmed that white flowered genotypes can have different genetic constitutions as proposed by Ayyar and Balasubramanian (1936) and Davis (1991). The present results vary with those who supported monogenic and digenic inheritance pattern for flower colour which could be due to the different genetic material used in the study.

Considering the occurrence of various shades of the colours observed in this study and 22 genes known for flower colour in the related genus *Pisum*, it is apparent that more than three loci govern flower colour in chickpea (Kumar, 1997). Further studies are therefore warranted to investigate the evolution of this character.

5.2 Inheritance of seed protein content

Legumes are a major source of protein in most developing countries, containing two to three times as much protein as cereals. Chickpea is an important pulse crop of India with seed protein content ranging from 12.6-30.5% (Singh, 1985), showing large variation for this character. Kumar *et al.* (1982) observed a linkage between blue flower colour, high protein content and small seed size. In order to break this linkage and recover segregants with high protein content, an understanding of its inheritance pattern is essential. Thus, a study was undertaken to investigate the inheritance of seed protein content in two selected crosses of chickpea involving high protein genotype, T 39-1 as common male parent for moderate and low protein female parents, P 9623 and RS 11.

In the F_1 generation of both the crosses, the low protein content showed dominance over high protein content. This view varies with the results of Singh *et al.* (1992) who showed partial and over dominance for protein content. But Garcia *et al.* (1985) reported that segregation pattern for protein content varied with the crosses, the genetic system being heterogeneous. The cross P 9623 x T 39-1 showed transgressive segregation towards low protein parent. This indicated the presence of some genes for low protein content in the high protein parent apart from the genes for high protein content resulting in non-isodirectional distribution of genes for protein content. The other cross RS 11 x T 39-1 did not show transgressive segregation which could be due to the isodirectional distribution of genes for protein content.

In the present study, the F_2 frequency distribution was near normal for both the crosses. The normal distribution indicates multigenic control of this trait. It was slightly skewed towards the low protein parent in the RS 11 x T 39-1 cross suggesting the dominance of low protein over high protein content. Rang *et al.* (1986) also indicated the presence of multigenic interactions for this trait. Tyagi and Singh (1988) found that the differences did not have cytoplasmic or extrachromosomal basis and maternal effects as reported by Sandhu *et al.* (1968) and Tyagi *et al.* (1982). Singh *et al.* (1990) reported that protein content followed normal distribution pattern.

The multigenic control also suggests significant influence of environment on seed protein content. Substantial genotype x environment interaction has been reported for this trait by Krober (1970), Sandhu *et al.* (1974), Dahiya *et al.* (1982), Sengupta *et al.* (1986) and Singh *et al.* (1990). Location had the greatest influence on seed protein content in chickpea more than growing season (Singh *et al.*, 1983 and Singh *et al.*, 1990). However, high heritability for protein content was also observed by Sandhu *et al.* (1989) which indicates that relatively quick progress in breeding for this character should be possible. Singh *et al.* (1990) identified some kabuli chickpea lines which maintained high protein content with low variability when grown for two seasons over two very different growing locations. This indicates the possibility of selecting kabuli chickpea lines with higher protein content.

In the present study, the low association of protein content with seed yield in both the crosses showed the possibility of improvement of these characters by simultaneous

selection. Thus, T 39-1 and T-1-A which are both high protein genotypes, may be used as parents with existing commercial varieties. Subsequent selection for high protein content and high seed yield may help breeders to recover cultivars with high yield as well as high protein content.

5.3 Inheritance of crude fibre content

Desi and kabuli chickpeas differ not only in morphology, but also in nutrition i.e. fibre content. Desi types have higher fibre content than kabuli types. For maximum recovery of *dhal*, low fibre content is desirable. Therefore, an investigation was carried out to study the inheritance of crude fibre content in two crosses of chickpea wherein the parents used differed from each other significantly for this character.

In the cross P 9623 x T 39-1, the F_1 mean was almost equal to that of high fibre parent suggesting the dominance of high crude fibre over low crude fibre content. This is in accordance with the reports of Gil and Cubero (1993) who reported the dominance of high seed fibre over low seed fibre content. This character showed transgressive segregation towards both the parents indicating non-isodirectional distribution and presence of genes for high and low crude fibre content in both the parents. This could also be due to recombination between the genomes of two parents resulting in complementation when they segregated in F_2 generation. Therefore, there is possibility of developing genotypes with very low or high fibre content depending on the requirement.

In the cross RS 11 x T 39-1, F_1 generation showed higher mean value than the mid parental value and almost equal to high fibre parent. This indicated the dominance of high crude fibre over low crude fibre content. This is also in accordance with the results of Gil and Cubero (1993) who reported dominance of high seed fibre over low seed fibre. In this cross transgressive segregation was obtained towards high crude fibre content suggesting non-isodirectional distribution of genes for high crude fibre content and presence of genes for high fibre content in low parent as well. Thus, the isolation of genotypes with very high crude fibre content and transfer of this trait to the commercial varieties may be possible.

The F_2 values showed near normal frequency distribution which was indicative of the multigenic control of the character. Kumar and Singh (1989) also obtained near normal distribution in F_2 generation for seed coat thickness and suggested the involvement of several genes governing this trait. But these results are contrary to those of Gil and Cubero (1993) who observed that the seed coat thickness or seed fibre exhibited monogenic inheritance with thick seed coat or high fibre being dominant to thin seed coat or low fibre content.

Thus, high fibre content in F_1s and near normal distribution pattern in F_2s suggest dominance for high fibre content and the role of several genes governing this character. Both the crosses showed significant difference and wider range for this character. This suggested presence of variability that could be exploited. Singh *et al.* (1980) also reported variation for this character. The cross RS 11 x T 39-1 involving desi parent RS 11, showed

higher fibre content than the other cross. Singh (1984) also reported higher fibre content for desi types.

The results of the present study showed the recovery of desi type segregants with relatively thinner seed coats (Appendix B). This trait could be stabilized in later generations which may produce a higher proportion of *dhal* than those available at present. This was also suggested by Kumar and Singh (1989). The results also indicated the development of genotypes with very high crude fibre content or thicker seed coat which might offer resistance to root diseases and bruchids (Kumar and Singh, 1989). High heritability was also reported for this character (Kharrat *et al.*, 1990). This suggested that improvement by selection for fibre content in a breeding programme is possible at a relatively quicker pace.

5.4 Correlation coefficients

Correlation coefficients indicate relativity of the association between traits under consideration. These furnish a realistic basis for the allocation of weightage to each of the contributing components in deciding upon a suitable selection criteria for the genetic improvement of complex characters like seed yield and help in selection for simultaneous improvement of these characters. In the present investigation, correlation coefficients were worked out between seed yield and its components, among the components themselves and with seed protein and crude fibre content in two crosses of chickpea.

5.4.1 Cross I: P 9623 x T 39-1

Phenotypic correlation studies were carried out in the F_2 generation of this cross as a whole

irrespective of flower colour and flower colourwise i.e. within white, pink and blue flowered plants.

In this cross, seed yield per plant showed high positive association with number of primary branches per plant (Salimath and Bahl, 1986; Mishra *et al.*, 1988; Sandhu *et al.*, 1988; Singh *et al.*, 1989; Tagore and Singh, 1990; Bejiga *et al.*, 1991; Jadhav *et al.*, 1992; Chavan *et al.*, 1994; Tripathi *et al.*, 1995 and Manjare *et al.*, 1997), secondary branches per plant (Jivani and Yadavendra, 1988; Sharma and Maloo, 1988; Uddin *et al.*, 1990; Yadav, 1990; Bejiga *et al.*, 1991; Chhina *et al.*, 1991; Abdali, 1992; Rao *et al.*, 1994; Khorgade *et al.*, 1995 and Manjare *et al.*, 1997), pods per plant (Salimath and Bahl, 1986; Jivani and Yadavendra, 1988; Reddy and Rao, 1988; Sandhu *et al.*, 1988; Sharma and Maloo, 1988; Tagore and Singh, 1990; Yadav, 1990; Bejiga *et al.*, 1991; Chhina *et al.*, 1991; Abdali, 1992; Bouslama *et al.*, 1992; Jadhav *et al.*, 1992; Chavan *et al.*, 1994; Rao *et al.*, 1994; Sarvaliya and Goyal, 1994; Khorgade *et al.*, 1995; Singh *et al.*, 1995; Tripathi *et al.*, 1995; Ozdemir, 1996 and Manjare *et al.*, 1997) and seeds per plant (Reddy and Rao, 1988; Sadhu and Mandal, 1989; Yadav, 1990; Bejiga *et al.*, 1991; Kharrat *et al.*, 1991; Akdag and Sehirali, 1992; Dasgupta *et al.*, 1992; Jadhav *et al.*, 1992; Sathe *et al.*, 1993 and Chand and Singh, 1997) and non-significant association with the other characters namely plant height (Reddy and Rao, 1988 and Jahhar and Mane, 1991), number of seeds per pod, 100-seed weight (Reddy and Rao, 1988), seed protein content and crude fibre content. But Chavan *et al.* (1993) reported positive association of seed protein content with seed yield per plant. Association was very high between seed yield per plant and pods and seeds per plant.

In the present study, high positive association of seed yield per plant was observed with number of pods per plant and seeds per plant in all the three flower colour types. Pink and blue flowered plants only showed high positive association of seed yield per plant with primary branches per plant which could be due to high positive association of primary branches per plant with number of pods and seeds per plant in these plants. Only pink flowered plants showed high positive association of secondary branches per plant with seed yield per plant which is probably due to high positive association of secondary branches per plant with number of pods per plant and seeds per plant in this category. Among white flowered plants, negative association was found between seed yield per plant and plant height. Such results were reported by Sandhu and Mangat (1995) and Mathur and Mathur (1996) in chickpea genotypes. This might be due to negative association of plant height with number of pods and seeds per plant.

Seed protein content showed negative correlations with number of seeds per pod and 100-seed weight in this cross. Pundir *et al.* (1991) also obtained a negative correlation between protein content and 100-seed weight. But this varies with the results of Singh *et al.* (1990) who reported non-significant correlation. In this cross as the seed weight increased, protein content decreased. As a kabuli parent is involved, a proper balance should be maintained in selection for high protein and bolder seed size. Seed protein content showed non-significant correlations with all other characters (Sandhu *et al.*, 1989 and 1991, and Kharrat *et al.*, 1990).

In this study, only blue flowered plants showed negative correlation of protein content with 100-seed weight, while white and pink flowered plants showed negative but non-significant correlation. This supports the results of Kumar *et al.* (1982) who reported linkage for blue flower colour, high protein and small seed size. This could be explained by the presence of high seed protein content in T 39-1, blue flowered parent having small seed size compared to the other parents. All the three flower colour types showed non-significant correlations of seed protein content with number of seeds per pod and with other characters.

Crude fibre content showed high negative association with plant height and 100-seed weight, and negative association with number of primary branches per plant in this cross. Singh *et al.* (1980) had also reported negative association between seed coat percentage or crude fibre and seed mass. But Kharrat *et al.* (1990) showed non-significant association between fibre content and 100-seed weight. Among all the three flowered types also, negative association was found between this trait and 100-seed weight. It might be due to the bold seeded kabuli parent, P 9623 showing lowest crude fibre content. Thus, as the seed weight increased crude fibre content decreased.

Plant height showed positive association with number of primary branches per plant and secondary branches per plant (Choudhury and Mian, 1988) in the cross and in blue flowered plants. It showed positive association with 100-seed weight (Reddy and Rao, 1988 and Sathe *et al.*, 1993) in the cross and in white flowered plants. This could be due to negative association of 100-seed weight and plant height with number of pods and seeds per plant in white flowered plants. It showed negative association with number of pods per

plant, seeds per plant and seeds per pod resulting in its negative association with seed yield per plant in white flowered plants. It also showed negative association with number of seeds per pod in the whole cross. This may be due to an imbalance between vegetative and reproductive growth.

Positive correlations were found between number of primary and secondary branches per plant (Sandhu *et al.*, 1991), number of primary branches per plant and pods per plant (Sandhu *et al.*, 1991), and number of pods per plant and seeds per plant in the cross and in all the three flower colour types. Reddy and Rao (1988), Bejiga *et al.* (1991), Abdali (1992), Dasgupta *et al.* (1992) and Sathe *et al.* (1993) also reported significant positive correlation between number of pods and seeds per plant.

Number of primary branches per plant exhibited negative association with number of seeds per pod in all except blue flowered plants and with crude fibre content in this cross. It showed positive association with number of seeds per plant in all cases except white flowered plants which resulted in its non-significant association with seed yield in this type.

Number of secondary branches per plant showed positive relationship with number of pods per plant (Bejiga *et al.*, 1991; Chhina *et al.*, 1991; Sandhu *et al.*, 1991 and Abdali, 1992) and number of seeds per plant (Bejiga *et al.*, 1991) in all types except white flowered plants in which it did not show positive relationship with seed yield per plant. It also showed negative relationship with number of seeds per pod in all types except blue flowered plants.

Number of pods per plant showed negative correlation with 100-seed weight (Lal *et al.*, 1993) in white flowered plants while number of seeds per plant had negative correlation with 100-seed weight (Sadhu and Mandal, 1989) in the cross and in white flowered plants indicating decrease in seed weight with increase in number of pods and seeds per plant. Number of seeds per plant had positive correlation with number of seeds per pod in this cross (Dasgupta *et al.*, 1992 and Sathe *et al.*, 1993).

Number of seeds per pod had negative relationship with 100-seed weight in only white flowered plants. Such negative relationship was also reported by Sadhu and Mandal (1989), Pundir *et al.* (1991), Dasgupta *et al.* (1992) and Sathe *et al.* (1993).

In this cross (P 9623 x T 39-1) as a whole, seed yield was positively correlated with number of primary branches, secondary branches, pods and seeds per plant. Number of seeds per pod was positively correlated with number of seeds per plant. Thus, all these characters could be indirectly used for seed yield improvement. 100-seed weight was negatively correlated with number of seeds per plant but non-significantly correlated with seed yield per plant. Therefore, selection for more number of seeds per plant with proper seed weight is essential to improve seed yield. Waldia *et al.* (1988) and Eser *et al.* (1991) also emphasized the importance of 100-seed weight in yield improvement.

Seed protein content was negatively correlated with 100-seed weight. Therefore, a simultaneous selection for high protein and bolder seeds may be done. This will combine the advantages of bold kabuli seeds with high protein content as kabuli parent is involved in

this cross. Crude fibre content and 100-seed weight were negatively correlated so that selection for heavier seed weight would result in low fibre content which could be effectively used for relatively higher *dhal* recovery.

In the whole cross and all the three flowered plants, seed yield was positively correlated with number of pods and seeds per plant. Crude fibre content was negatively correlated with 100-seed weight in all types. Seed protein content was significantly and negatively correlated with 100-seed weight in the whole cross and in blue flowered plants. Seed protein and crude fibre content showed little association with other traits including seed yield. Thus, the three flower colour types did not differ much in the correlations between the characters. This suggests that selection of any of these types may bring about same change.

Therefore, to develop high yielding genotypes with high protein and low fibre content with high nutritive value and suitable for maximum *dhal* recovery, simultaneous selection should be done for more number of pods, bolder seeds and high protein content.

5.4.2 Cross II: RS 11 x T 39-1

Phenotypic correlation coefficients were worked out in the F_2 generation of this cross as a whole and within white, pink and blue flowered plants.

The seed yield showed positive association with number of pods per plant (Sindhu and Prasad, 1987; Malik *et al.*, 1988; Mishra *et al.*, 1988; Reddy and Rao, 1988; Singh

et al., 1989; Uddin *et al.*, 1990; Yadav, 1990; Bejiga *et al.*, 1991; Kharrat *et al.*, 1991; Abdali, 1992; Akdag and Sehirali, 1992; Varghese *et al.*, 1993; Arora and Kumar, 1994; Bhambota *et al.*, 1994; Deshmukh and Patil, 1995; Sandhu and Mangat, 1995; Singh *et al.*, 1995; Mathur and Mathur, 1996 and Chand and Singh, 1997) and seeds per plant (Reddy and Rao, 1988; Sadhu and Mandal, 1989; Yadav, 1990; Bejiga *et al.*, 1991; Kharrat *et al.*, 1991; Akdag and Sehirali, 1992; Dasgupta *et al.*, 1992; Jadhav *et al.*, 1992; Sathe *et al.*, 1993 and Chand and Singh, 1997) in all the four categories.

In the whole cross, seed yield per plant showed significant positive association with plant height (Paliwal *et al.*, 1987; Shukla, 1988; Ali, 1990; Yadav, 1990; Arora and Kumar, 1994; Bhambota *et al.*, 1994 and Sarvaliya and Goyal, 1994), number of primary branches per plant (Salimath and Bahl, 1986; Mishra *et al.*, 1988; Sandhu *et al.*, 1988; Singh *et al.*, 1989; Tagore and Singh, 1990; Bejiga *et al.*, 1991; Jadhav *et al.*, 1992; Chavan *et al.*, 1994; Tripathi *et al.*, 1995 and Manjare *et al.*, 1997) and number of seeds per pod (Sindhu and Prasad, 1987; Malik *et al.*, 1988; Sandhu *et al.*, 1988, 1989 and 1991; Shukla, 1988; Tagore and Singh, 1990; Singh and Rheenen, 1994 and Manjare *et al.*, 1997). Seed yield per plant showed positive association with number of secondary branches per plant (Jivani and Yadavendra, 1988; Sharma and Maloo, 1988; Uddin *et al.*, 1990; Yadav, 1990; Bejiga *et al.*, 1991; Chhina *et al.*, 1991; Abdali, 1992; Rao *et al.*, 1994; Khorgade *et al.*, 1995 and Manjare *et al.*, 1997) in all the cases except in white flowered types which might be due to non-significant association of number of secondary branches per plant with number of pods and seeds per plant in this type.

Positive association of seed yield per plant was seen with plant height and number of seeds per pod among blue flowered plants, while in white and pink flower types this was not observed. This could be due to association of plant height and number of seeds per pod with number of seeds per plant in this type. Among pink flowered plants, positive association of seed yield per plant with primary branches per plant was recorded, while it was not recorded in white and blue flowered types. This could be due to non-significant association of primary branches per plant with number of pods per plant and seeds per plant in these types. Seed yield per plant showed non-significant association with the other characters namely plant height (Reddy and Rao, 1988 and Jahhar and Mane, 1991), number of seeds per pod, 100-seed weight (Reddy and Rao, 1988), seed protein content and crude fibre content. But Chavan *et al.* (1993) reported positive association of seed protein content with seed yield per plant.

In this cross, seed protein content showed positive correlation with number of pods per plant which could be explained by the negative correlations between seed protein content and 100-seed weight, and number of pods per plant and 100-seed weight. This varies with the observations of Sandhu *et al.* (1989) who found negative correlation between protein content and number of pods per plant. Seed protein content showed negative correlations with number of seeds per pod, 100-seed weight (Pundir *et al.*, 1991) and crude fibre content. This varies with the results of Kharrat *et al.* (1990) who reported non-significant correlation of seed protein content with 100-seed weight and crude fibre content. Singh *et al.* (1990) also reported non-significant correlation between seed protein content and 100-seed weight. Negative association with crude fibre could be due to the

parent RS 11, which is a desi type having high crude fibre content but low seed protein content compared to the other parents.

Only in blue flowered plants, seed protein content was highly negatively correlated with 100-seed weight as is evident from the high protein content of blue flowered parent, T 39-1 having small seeds. This is in accordance with reports of Kumar *et al.* (1982) who observed linkage for blue flower colour, high protein and small seed size. Among white flowered plants, protein content showed positive correlation with plant height. With all the other characters non-significant correlations were recorded which are in accordance with the results of Sandhu *et al.* (1989 and 1991) and Kharrat *et al.* (1990).

Crude fibre content showed negative association with plant height and number of secondary branches per plant in this cross and in pink flowered plants. It showed positive association with 100-seed weight which could be explained on the basis of negative association of crude fibre and seed protein content, and seed protein content and 100-seed weight. This is contrary to the reports of Singh *et al.* (1980) and Kharrat *et al.* (1990) who reported non-significant association between seed coat thickness and seed mass.

Plant height showed positive correlation with number of primary branches per plant in all types except white flowered plants where it showed no correlation. It also showed significant positive correlations with number of secondary branches per plant (Choudhury and Mian, 1988), pods per plant and seeds per plant as it was also correlated positively with seed yield per plant in this cross. Among blue flowered plants also, it showed positive

correlations with number of secondary branches per plant and seeds per plant as it was positively related with seed yield per plant. Among pink flowered plants it showed positive correlation with 100-seed weight (Reddy and Rao, 1988 and Sathe *et al.*, 1993). In this cross yield increased with increase in plant height.

In all the cases, positive association was found between number of primary branches and secondary branches per plant (Sandhu *et al.*, 1991), and number of pods and seeds per plant (Reddy and Rao, 1988; Bejiga *et al.*, 1991; Abdali, 1992; Dasgupta *et al.*, 1992 and Sathe *et al.*, 1993).

Primary branches per plant showed positive correlations with number of pods per plant (Sandhu *et al.*, 1991) and seeds per plant in this cross and in pink flowered plants which can be explained on the basis of correlation of this character with yield in these types.

Secondary branches per plant exhibited positive correlations with number of pods per plant (Bejiga *et al.*, 1991; Chhina *et al.*, 1991; Sandhu *et al.*, 1991 and Abdali, 1992) and seeds per plant (Bejiga *et al.*, 1991) in all types except white flowered type which resulted in its positive relationship with seed yield per plant in all types except white flowered plants.

Number of pods per plant (Lal *et al.*, 1993) and seeds per plant (Sadhu and Mandal, 1989) showed significant negative correlations with 100-seed weight in this cross. Number of seeds per plant also showed positive correlation with number of seeds per pod (Dasgupta

et al., 1992 and Sathe *et al.*, 1993) in the cross and in blue flowered plants, which also showed positive correlation with seed yield per plant in these categories. This may be due to the smaller seed size of blue flowered parent, T 39-1.

Thus, in this cross seed yield was positively correlated with plant height, number of primary branches, secondary branches, pods and seeds per plant, and number of seeds per pod. All these characters were correlated among themselves. Therefore, selection for these characters may improve seed yield. 100-seed weight was negatively correlated with number of pods and seeds per plant, but non-significantly correlated with seed yield. So selection of these yield components may reduce the seed weight. Hence, a simultaneous selection for number of pods and seeds with bolder seed weight may be helpful for seed yield improvement.

Seed protein content and crude fibre content were negatively correlated with each other and non-significantly correlated with seed yield. Seed protein content was negatively correlated with 100-seed weight, while crude fibre content was positively correlated with 100-seed weight. Therefore, to get high seed yield coupled with bolder seeds and high seed protein, simultaneous selection for these characters is required. Selection for low crude fibre content may not be required as selection for high protein will lower the fibre content.

Considering all the three flowered types, seed yield showed positive correlations with number of secondary branches, pods and seeds per plant. Seed protein and crude fibre content were negatively correlated with each other and largely unrelated with other

characters including seed yield. The three flowered types showed almost similar correlations between the characters hence, any of them could be selected for seed yield improvement. However, seed protein and 100-seed weight were highly negatively correlated in blue flowered plants only. Hence, simultaneous selection is required for the improvement of these characters

In this cross (RS 11 x T 39-1) crude fibre content was high. It showed negative correlation with seed protein content but positive correlation with 100-seed weight. Therefore, to develop high yielding genotypes with bolder seeds and high fibre content a simultaneous selection for seed yield and seed weight should be done which would also improve fibre content. This would help to develop resistance to root diseases and bruchids (Kumar and Singh, 1989).

5.5 Variability for characters

Varieties superior in quality and quantity demand breeders to deal with polygenic characters showing continuous variation wherein careful selection must be exercised in the early generations to get the desirable final product. More diverse the parents, the greater are the chances of recovering desirable combination and obtaining higher heterotic expression in the hybrids. Thus, crop improvement depends on the magnitude of genetic variability in the base population. Chickpea is a self pollinated crop and demands extensive studies to investigate and exploit the existing variability. Therefore, the present investigation was taken up to find out significant differences for various characters among the three parents P 9623, RS 11 and T 39-1 and between the two crosses P 9623 x T 39-1 and RS 11 x T 39-1.

5.5.1 Among parents

Significant differences were found among the three parents for various characters studied indicating variability among the three parents. This is in accordance with the results of Choudhury and Mian (1988), Sandhu *et al.* (1988) and Bahl *et al.* (1991).

The characters plant height, number of primary branches per plant and number of secondary branches per plant were higher in both P 9623 and T 39-1 compared to RS 11 and the difference between P 9623 and T 39-1 was not significant. Hence both these parents could be selected for these characters. Variability for these characters was reported by Sadhu and Mandal (1989), Samal and Jagadev (1989), Sharma *et al.* (1990), Pundir *et al.* (1991), Sandhu *et al.* (1991) and Chavan *et al.* (1994). But Rana *et al.* (1995) reported no variation for plant height.

Number of pods and seeds per plant were higher in RS 11 and T 39-1 compared to P 9623. RS 11 and T 39-1 showed no significant difference for these characters. Singh and Singh (1989), Sandhu *et al.* (1991) and Rao *et al.* (1994) showed variability for number of pods per plant.

The number of seeds per pod was higher in RS 11 compared to P 9623 and T 39-1. It varies with Rana *et al.* (1995) who observed no variation for this. 100-seed weight showed a decreasing trend from P 9623 to RS 11 to T 39-1. This supports the results of Singh and Singh (1989), Singh *et al.* (1990), Waldia *et al.* (1991), Rao *et al.* (1994), Gil *et al.* (1996) and Patil and Meshram (1996).

Seed protein content showed a decreasing trend from T 39-1 to P 9623 to RS 11. Variability for this trait was reported by Sharma *et al.* (1990), Singh *et al.* (1990), Pundir *et al.* (1991), Waldia *et al.* (1991) and Chavan *et al.* (1993). Rana *et al.* (1995) noted no variability for this. Crude fibre content showed a decreasing trend from RS 11 to T 39-1 to P 9623 (Gil *et al.*, 1996).

Seed yield was lower in T 39-1 compared to RS 11 and P 9623, which within themselves showed no significant difference. Variation for seed yield was recorded by Sadhu and Mandal (1989), Samal and Jagadev (1989), Singh and Singh (1989), Sharma *et al.* (1990), Pundir *et al.* (1991), Sandhu *et al.* (1991), Chavan *et al.* (1994), Rao *et al.* (1994) and Patil and Meshram (1996).

White flowered kabuli type parent, P 9623 combined the qualities of being taller with more number of primary and secondary branches per plant, heavier seed weight and higher seed yield per plant. Its seed coat colour is salmon white. Therefore, the qualities of higher seed yield per plant with mostly preferred seed coat colour and seed type could be transferred to its progeny. It was also effective in transfer of these characters to the succeeding generations as was evident from the cross P 9623 x T 39-1 showing heavier 100-seed weight with many kabuli type and salmon white coloured seeds in the F_2 generation (Appendix A).

Light brown coloured desi type parent, RS 11 combined the yield contributing characters such as higher seed yield per plant, more number of pods and seeds per plant and

more number of seeds per pod, and higher crude fibre content. Thus, it combined the components of higher yield with a mechanism to offer resistance to root diseases and bruchids which could be successfully used in various breeding programmes involving transfer of resistance characters. It could also transfer these characters effectively to the progeny as was seen in the cross RS 11 x T 39-1 having these characters in greater form.

Blue flowered intermediate type parent, T 39-1 was taller with more number of primary branches, secondary branches, pods and seeds per plant. These characters could be used for indirect selection for seed yield. It had small seed size with lowest 100-seed weight among the three parents. It had highest seed protein content among the three parents which could be effectively used in the breeding programmes for nutritional improvement.

Thus, all the three parents included in this study had some good characters which could be combined in some of the segregants derived from the crosses P 9623 x T 39-1 and RS 11 x T 39-1.

5.5.2 Between crosses

There were highly significant difference of means for various characters studied indicating some amount of variability between the crosses, which facilitates recovery of desirable characters in greater intensity by selection in these crosses.

Differences were highly significant between the two crosses for plant height, number of pods per plant, number of seeds per plant, number of seeds per pod, 100-seed

weight, seed protein content and crude fibre content. The variations in these characters are in accordance with the studies of El-Shatnawi (1988), Singh and Rao (1991) and Panchbhai *et al.* (1992) in the segregating generations.

The ranges for these characters in both the crosses were also high indicating variation between the individual plants. This variation among the plants could be utilized in selection for desirable characters.

Common male parent, T 39-1 showed higher plant height and more seed protein content than the other two parents, number of pods per plant, number of seeds per plant and crude fibre content intermediate to both the parents, and 100-seed weight and number of seeds per pod lower than the other two parents. As this was a common parent, the differences in the two crosses may be largely attributed to the influence of the two parents P 9623 and RS 11 in the respective crosses.

Significant difference was found for plant height between the crosses. The cross P 9623 x T 39-1 had taller plants and wider range than the other cross RS 11 x T 39-1. This is in accordance with the results of Kidambi *et al.* (1988) and Patil *et al.* (1996) but against the reports of El-Shatnawi (1988) who reported variation for all traits studied except plant height. This could be due to taller plants in the parent P 9623 than the parent RS 11. Thus, parent P 9623 could transfer its character to the succeeding generations. The cross P 9623 x T 39-1 provided greater scope for selection for this character because of its wider range.

The crosses did not show significant differences with respect to number of primary and secondary branches per plant. This supports Jahagirdar *et al.* (1996) who reported low variation for these characters, but varies with Kidambi *et al.* (1988) and Patil *et al.* (1996) who showed variability for these traits. However, the range was wider in the cross P 9623 x T 39-1 than the other cross permitting selection for these characters in greater magnitude in this cross.

The cross RS 11 x T 39-1 had higher mean for number of pods per plant, seeds per plant and seeds per pod compared to P 9623 x T 39-1. Variation for these characters was reported by Singh and Rao (1991) and Patil *et al.* (1996). This could be due to more number of pods per plant, seeds per plant and seeds per pod in the parent RS 11 compared to the parent P 9623. Thus, RS 11 could transfer its characters to its progeny. However, the range was higher in P 9623 x T 39-1 than the other cross suggesting possibility of selection for these characters in this cross as well.

The cross P 9623 x T 39-1 had bolder seeds with high protein content than the other cross. This could be due to the presence of these characters in intense form in P 9623 than in RS 11. From this result, it can be concluded that heavier 100-seed weight and high seed protein content could be obtained simultaneously. The range was also wider in P 9623 x T 39-1 cross compared to the other cross suggesting further improvement in this cross. Variation for 100-seed weight was reported by Kumar and Singh (1989) and Patil *et al.* (1996) and for seed protein content by Kharrat *et al.* (1990). In both the crosses, within the three flower coloured plants, mean value of seed protein content was highest and 100-seed

weight was lowest in blue flowered plants showing the linkage between blue flower colour, high protein and small seed size. This was earlier reported by Kumar *et al.* (1982). Thus, the present results also have indicated some linkage. Segregants with bolder seed size and high protein content may be recoverable by careful selection in large populations. Crude fibre content did not show such tendency with these characters.

Crude fibre content was also significantly different in the two crosses. RS 11 x T 39-1 cross had higher crude fibre content and wider range than the cross P 9623 x T 39-1, which was due to more fibre content in the parent RS 11 than in P 9623. Kumar and Singh (1989) and Kharrat *et al.* (1990) had also observed significant variation among the crosses studied for fibre content.

Both the crosses showed no difference with respect to seed yield per plant giving almost similar seed yield. This varies with the results of Singh and Rao (1991), Panchbhai *et al.* (1992) and Patil *et al.* (1996) who reported variation for this character. But the range was higher in the cross P 9623 x T 39-1 than the other cross. The maximum value of yield was also higher in this cross indicating the scope of direct selection for seed yield.

Cross P 9623 x T 39-1 was better with respect to plant height, 100-seed weight and seed protein content than the cross RS 11 x T 39-1, while cross RS 11 x T 39-1 performed better with respect to number of pods per plant, seeds per plant and seeds per pod compared to the cross P 9623 x T 39-1.

For milling and stock feed purposes, thin seed coat with less fibre content is preferred. So cross P 9623 x T 39-1 having less fibre content was considered better than the cross RS 11 x T 39-1. Cross P 9623 x T 39-1 combined the characters of heavier seed weight and higher seed protein content with kabuli type of seed, hence more preferred than the other cross.

Thus, for the improvement of quality characters like seed protein and fibre content along with seed yield, cross P 9623 x T 39-1 could be used as the range was higher in this cross. For the improvement of yield indirectly through number of pods and seeds per plant, cross RS 11 x T 39-1 was found effective. Higher crude fibre content of the cross RS 11 x T 39-1 could be used for developing lines resistant to root diseases and bruchids.

5.6 Heterosis

Heterosis or hybrid vigour is the manifestation of heterozygosity in F_1s as compared to their homozygous parents. It occurs in both self pollinating and out crossing species and often exploited to increase the yield potential of crop plants. The magnitude of heterosis encountered in any crop species is of paramount importance in deciding as to whether or not heterosis breeding is practical. In chickpea, the first report of hybrid vigour for pods per plant was given by Pal (1945) and later heterosis was demonstrated by Ramanujam *et al.* (1964). Therefore, heterosis was studied and the results are discussed below.

Heterotic effects varied with the crosses and characters in the present study (Shinde and Deshmukh, 1990).

In both the crosses positive mid parent and better parent heterosis were observed for seed yield indicating recovery of F_1s with higher seed yield compared to the parents. These values were higher in the cross P 9623 x T 39-1 than in the other cross indicating its exploitation in this cross. However, no significant difference was observed between the two F_1s as the increased vigour in the cross P 9623 x T 39-1 compensated the relatively low seed yield of the parent P 9623. This suggested the selection of both the crosses for further improvement. Mid parent and better parent heterosis for seed yield was reported by Arora and Pandya (1987), Tewari and Pandey (1987), Kumar and Bahl (1988), Bahl and Kumar (1989), Mian and Bahl (1989), Pandey and Tiwari (1989), Rao and Chopra (1989), Arora (1990), Khan *et al.* (1990), Shinde and Deshmukh (1990, 1993), Bejiga and Singh (1991), Gumber *et al.* (1992), Kamatar *et al.* (1996) and Patil *et al.* (1996). The values reported in the present study are in the range of those obtained by Shinde and Deshmukh (1990) and Gumber *et al.* (1992).Values are more than that reported by Pandey and Tiwari (1989).

Seed protein content was found to have negative mid parent and better parent heterosis in both the crosses. This varies with the results of Salimath *et al.* (1988) and Kamatar *et al.* (1996) who reported heterosis for this character. But the seed protein content was comparatively higher in F_1 and F_2 generations of the cross P 9623 x T 39-1.

Crude fibre content showed positive mid parent heterosis in both the crosses and positive better parent heterosis in only P 9623 x T 39-1 cross. But the mid parent heterosis value was higher in the cross RS 11 x T 39-1. For this character, cross P 9623 x T 39-1

showing lesser mid parent heterosis and low crude fibre content was preferred for maximum recovery of *dhal*.

Plant height had negative mid parent and better parent heterosis in the cross P 9623 x T 39-1, while it had positive mid parent heterosis and negative better parent heterosis in the cross RS 11 x T 39-1. Thus, the two taller parents P 9623 and T 39-1 did not result in increased vigour when crossed, but the shorter parent RS 11 and taller parent T 39-1 showed increased vigour when crossed. Heterosis for plant height was reported by Rao and Chopra (1989).

Positive mid parent heterosis and negative better parent heterosis were observed for number of primary and secondary branches per plant in both the crosses indicating the increased vigour of F_1s over the mid parent. Heterosis for these characters was also reported by Rao and Chopra (1989), Shinde and Deshmukh (1990) and Kamatar *et al.* (1996).

Mid parent heterosis was positive and better parent heterosis was negative for number of pods and seeds per plant in the cross P 9623 x T 39-1, while mid parent and better parent heterosis were positive for these characters in the cross RS 11 x T 39-1. The values were higher in the cross P 9623 x T 39-1 wherein the parents differed for these characters significantly than the other cross RS 11 x T 39-1 in which the parents did not differ significantly for these characters. Tewari and Pandey (1987), Kumar and Bahl (1988), Bahl and Kumar (1989), Pandey and Tiwari (1989), Rao and Chopra (1989), Shinde and Deshmukh (1993) and Patil *et al.* (1996) reported heterosis for these characters.

Positive mid parent and better parent heterosis were observed for number of seeds per pod in the cross P 9623 x T 39-1, while positive mid parent heterosis and negative better parent heterosis were observed in the cross RS 11 x T 39-1. Values were higher in P 9623 x T 39-1 cross than in the other cross. Heterosis for this character was reported by Tewari and Pandey (1987), Kumar and Bahl (1988), Bahl and Kumar (1989), Rao and Chopra (1989) and Shinde and Deshmukh (1990 and 1993).

100-seed weight exhibited positive mid parent and better parent heterosis in the cross RS 11 x T 39-1, and positive mid parent heterosis and negative better parent heterosis in the cross P 9623 x T 39-1. But F_1 and F_2 of P 9623 x T 39-1 had heavier seed weight compared to that of the cross RS 11 x T 39-1 because of the heavier seed weight of P 9623. Rao and Chopra (1989), Shinde and Deshmukh (1993) and Satija *et al.* (1993) observed heterosis for this character.

The data reflect that mid parent heterosis for seed yield per plant may be due to the cumulative effect of mid parent heterosis of yield components like number of primary branches, secondary branches, pods and seeds per plant, and seeds per pod in the P 9623 x T 39-1 cross. In the cross RS 11 x T 39-1 it may be due to the cumulative effect of mid parent heterosis of plant height, number of primary branches, secondary branches, pods and seeds per plant, seeds per pod and 100-seed weight.

Between the two crosses investigated, the cross P 9623 x T 39-1 had better heterotic values for traits like number of pods and seeds per plant, number of seeds per pod and seed

yield per plant. Cross RS 11 x T 39-1 was better for plant height, number of primary branches and secondary branches per plant, 100-seed weight and crude fibre content. Such differences probably reflect the differences in genetic architecture of the two female parents P 9623 and RS 11. The result was that seed yield per plant was almost similar in F_1s of the two crosses although seed yield was comparatively lower in P 9623.

Comparing both the crosses, cross P 9623 x T 39-1 was found better performing owing to its heavier seed weight, high seed protein content, low crude fibre content and better seed yield compared to the other cross RS 11 x T 39-1.

SUMMARY

CHAPTER VI

SUMMARY

Genetic studies on flower colour, seed protein content, crude fibre content and qualitative and quantitative characters were carried out in two crosses of chickpea (*Cicer arietinum* L.) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P., during the *Rabi* Season 1997/98.

The investigation was done on parents and F_1 and F_2 generations of two crosses P 9623 x T 39-1 and RS 11 x T 39-1. The common male parent in both the crosses, T 39-1, is a high protein genotype with blue flowers, small pea shaped, gray coloured seeds and moderate fibre content. P 9623 is a large seeded, salmon white coloured, kabuli type with moderate protein, low fibre content and white flower colour. RS 11 has white flowers, medium sized yellow brown desi type seed, low protein and higher crude fibre content.

The parental, F_1 and F_2 seeds were sown in the post-rainy season, on 14 October, 1997. Sowing was done on deep vertisols on ridges 60 cm apart in an unreplicated block with an interplant spacing of 20 cm. Normal agricultural operations were done and plant protection measures were taken to grow a healthy crop.

Crosses between white and blue flowered parents produced pink F_1s and showed a supplementary type of gene action giving a ratio of 9 pink : 3 blue : 4 white flowers in the F_2 generations. Earlier studies indicated that the genetic constitution of the two white

flowered parents used in the present study was not similar. Thus, the present study has revealed the presence of three genes governing this trait. These are probably the C,B and P loci earlier reported in the literature. Therefore, the genetic constitution of the three parents and their respective F_1s are:

P 9623 : CCbbPP (White) **F_1 (P 9623 x T 39-1) : CCBbPp (Pink)**

RS 11 : ccBBPP (White) **F_1 (RS 11 x T 39-1) : CcBBPp (Pink)**

T 39-1 : CCBBpp (Blue)

The inheritance studies on seed protein content indicated dominance of low protein over high protein content. It appears that the trait is under multigenic control as its near normal distribution in the F_2 generations indicate continuous variation. The studies showed transgressive segregation towards low protein content in the cross P 9623 x T 39-1 indicating the presence of some genes for low protein content in high protein parent as well.

Inheritance of crude fibre content in the two crosses showed dominance of high fibre over low fibre content. Continuous variation for this character suggested a multigenic control. Transgressive segregation was observed towards high fibre content in both the crosses, while in the cross P 9623 x T 39-1 it was observed towards low parent also. This indicates that genes for high and low fibre content were contributed by both the parents.

Correlation studies have indicated strong positive association of seed yield per plant with number of pods and seeds per plant in both the crosses. Such association suggests a possible role of these characters in yield improvement. Number of primary and secondary

branches per plant and number of seeds per pod were correlated to seed yield either directly or indirectly through number of pods and seeds per plant. In the cross P 9623 x T 39-1, seed protein and crude fibre content were negatively correlated with 100-seed weight. However, in the RS 11 x T 39-1 cross, these were negatively correlated with each other. With 100-seed weight, seed protein showed negative correlation, whereas crude fibre showed positive correlation. In both the crosses 100-seed weight, seed protein and crude fibre content were largely unrelated with other traits including seed yield. These findings suggest that simultaneous improvement for these characters should be possible.

The parents and F_2 generations of the two crosses revealed sufficient variability for the 10 characters studied. Among the parents, P 9623 was superior to the other parents for 100-seed weight. RS 11 had relatively more number of pods, seeds and seeds per pod and higher crude fibre content, while T 39-1 had high seed protein content, more number of primary and secondary branches, and taller plant stature. The cross P 9623 x T 39-1 was superior for plant height, 100-seed weight, seed protein and crude fibre content, and RS 11 x T 39-1 proved better for characters like number of pods and seeds per plant, and number of seeds per pod.

In both the crosses, heterosis was observed for number of primary and secondary branches, pods and seeds per plant, seeds per pod, 100-seed weight, crude fibre content and seed yield per plant. Studies revealed that the mid parent heterosis for seed yield in both the crosses was a cumulative effect of the heterosis for number of primary branches, secondary branches, pods and seeds per plant, and seeds per pod. Between the two crosses, P 9623

x T 39-1 had better heterotic effects for number of pods and seeds, seeds per pod and seed yield per plant. RS 11 x T 39-1 had relatively higher heterotic effects for plant height, number of primary and secondary branches, 100-seed weight and crude fibre content.

Conclusions

Based on the results of the present investigation the following conclusions are drawn:

1. Three genes governing flower colour were identified as C, B and P. The flower colour genotypes for the three parents were determined. These are:

   P 9623 : CCbbPP (White) F_1 (P 9623 x T 39-1) : CCBbPp (Pink)

   RS 11 : ccBBPP (White) F_1 (RS 11 x T 39-1) : CcBBPp (Pink)

   T 39-1 : CCBBpp (Blue)

2. Low protein showed dominance over high protein content and it appears that several genes govern this character.

3. Blue flowered plants had high seed protein content and small seed size compared to either white or pink flower types indicating linkage between the genes for the three characters.

4. High crude fibre exhibited dominance over low crude fibre content and is probably governed by at least several genes with small cumulative effects. Desi type seeds

with low fibre content were obtained. This has implications for increased *dhal* recovery from such segregants.

5. The cross P 9623 x T 39-1 was found relatively better for developing high yielding genotypes with high protein and low fibre content suitable for high nutrition and maximum *dhal* recovery purposes. In this cross, simultaneous improvement for high seed yield, high protein and low fibre content appears to be possible. This cross also produced relatively larger seeded kabuli segregants. The cross RS 11 x T 39-1 was relatively better for seed yield through selection for high number of pods and seeds. This cross was found relatively better for selection of high yielding genotypes with bolder seeds and high crude fibre content that might offer resistance to root diseases and bruchids.

6. The parent P 9623 has large kabuli seeds with low fibre content, RS 11 has higher seed yield and high fibre content, while T 39-1 has high seed protein content. Therefore, it may be possible to select segregants combining these characters from their crosses.

7. Studies on correlations, variability and heterosis suggested that P 9623 x T 39-1 cross is superior to RS 11 x T 39-1 based on seed weight, protein content and seed yield. The cross also showed low mean fibre content resulting in high *dhal* recovery.

Future strategy :

Future investigations should include complementation studies for flower colour so as to determine genotypes of different white coloured parents and find out the evolutionary relationships between chickpea, field pea and lentil. Similar studies on protein and fibre content using large populations of different genotypes in different environmental conditions are required to ascertain the genetics of these characters and the role of environment on their expression. One of the important objectives should be to break the linkage between high protein content and small seed size to recover segregants with high protein content and large seed size. Simultaneous selection for high protein content, high seed yield and large seed size should be carried out. Selection for desi type segregants with low fibre content would help in maximum recovery of *dhal*. Transfer of high fibre content to kabuli seeds may offer better resistance against bruchids and root diseases.

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[1] Original not seen

APPENDIX A

Individual plant data for various characters studied in F_2 generation of the cross P 9623 x T 39-1, *Rabi* 1997/98.

P. No.	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat color
1	W	50	8	16	130	93	0.7	27.0	26.8	3.1	25.1	K	SW
2	W	58	6	13	69	68	1.0	28.4	24.2	3.2	19.3	K	SW
3	P	50	6	18	73	72	1.0	19.2	29.9	4.8	13.8	I	Bl br
4	P	54	2	6	21	25	1.2	25.2	23.4	4.1	6.3	K	Br
5	W	50	7	17	131	114	0.9	18.9	27.9	3.2	21.6	K	SW
6	W	60	8	18	40	15	0.4	33.3	24.9	2.9	5.0	K	SW
7	W	58	6	17	32	18	0.6	37.8	26.8	2.6	6.8	K	SW
8	B	57	5	11	55	73	1.3	21.1	26.5	3.1	15.4	K	Gr
9	P	58	5	9	40	19	0.5	35.8	27.8	3.7	6.8	K	Br
10	W	55	5	11	55	45	0.8	30.0	25.0	3.1	13.5	K	SW
11	B	49	3	6	26	22	0.8	23.6	26.6	2.8	5.2	K	Br
12	B	57	6	15	74	62	0.8	21.0	28.8	3.7	13.0	I	Gr
13	P	50	5	18	125	94	0.8	23.3	26.4	4.1	21.9	I	Br
14	P	59	7	18	51	19	0.4	21.6	25.8	4.1	4.1	K	Br
15	P	50	5	13	77	53	0.7	18.5	25.5	4.6	9.8	I	Br
16	P	42	3	6	42	39	0.9	36.9	23.6	3.2	14.4	K	Br
17	P	52	3	6	32	27	0.8	26.3	28.1	4.0	7.1	K	Br bl
18	B	54	5	17	114	133	1.2	14.4	29.6	4.7	19.1	I	Br
19	P	50	2	6	25	27	1.1	21.9	26.3	5.1	5.9	K	Br
20	W	45	5	11	84	77	0.9	24.2	28.4	4.7	18.6	K	SW
21	P	50	4	11	102	93	0.9	17.1	30.0	6.5	15.9	I	Br bl
22	B	52	7	14	62	51	0.8	19.0	29.0	5.1	9.7	I	Gr
23	W	50	6	14	67	71	1.1	25.4	26.8	3.7	18.0	K	SW
24	P	55	4	9	32	51	1.6	28.0	28.4	6.0	14.3	K	Br bl
25	W	46	5	12	28	30	1.1	27.0	26.5	5.4	8.1	K	SW
26	B	52	3	6	22	15	0.7	20.0	29.9	5.2	3.0	K	Gr

Appendix A cont...

P. No.	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat colour
27	B	49	3	6	37	29	0.8	21.7	25.1	3.8	6.3	K	Br
28	P	49	3	7	81	83	1.0	22.0	26.0	5.6	18.3	I	Br
29	P	45	2	6	53	47	0.9	24.5	23.4	5.1	11.5	I	Br
30	P	47	3	4	20	25	1.2	16.4	26.7	5.3	4.1	I	Br
31	P	46	5	13	57	35	0.6	20.6	27.9	5.4	7.2	I	Br
32	P	43	8	18	52	35	0.7	15.1	26.2	5.6	5.3	K	Br
33	B	59	5	14	52	38	0.7	20.8	27.8	4.6	7.9	I	Gr
34	W	53	4	5	20	18	0.9	35.0	27.4	4.1	6.3	K	SW
35	W	62	5	15	19	15	0.8	37.3	25.5	3.4	5.6	K	SW
36	W	52	6	15	74	26	0.4	29.6	24.2	3.7	7.7	K	SW
37	P	48	2	4	19	24	1.3	20.0	23.5	4.9	4.8	K	Br
38	W	60	4	12	37	38	1.0	26.1	25.3	4.6	9.9	K	SW
39	P	60	3	6	41	37	0.9	20.8	22.7	4.6	7.7	K	Br
40	W	70	4	8	27	19	0.7	42.1	23.7	3.1	8.0	K	SW
41	P	52	6	4	85	87	1.0	16.6	27.7	4.8	14.4	K	Br
42	P	70	5	8	28	22	0.8	27.3	29.0	4.7	6.0	K	Br bl
43	B	58	2	6	53	48	0.9	18.3	26.3	4.1	8.8	K	Br
44	P	50	4	8	160	148	0.9	21.4	24.1	4.9	31.6	I	Br
45	P	52	6	17	92	81	0.9	30.7	23.9	5.1	24.9	I	Br
46	W	49	3	7	38	39	1.0	16.4	28.2	4.8	6.4	K	SW
47	P	52	4	13	43	40	0.9	26.0	22.8	4.2	10.4	K	Br
48	W	48	3	7	52	52	1.0	28.7	25.1	3.1	14.9	K	SW
49	B	52	3	7	61	60	1.0	20.0	26.3	3.7	12.0	K	Gr
50	W	50	3	7	29	41	1.4	20.2	27.6	5.5	8.3	K	SW
51	B	58	4	7	40	28	0.7	17.1	27.8	3.7	4.8	I	Gr
52	W	50	4	12	106	48	0.5	29.4	25.3	3.2	14.1	K	SW
53	W	53	5	8	85	78	0.9	20.6	24.2	2.8	16.1	K	SW
54	P	58	4	7	50	29	0.6	16.2	27.2	5.2	4.7	I	Br
55	P	50	3	6	21	20	1.0	22.0	25.8	4.3	4.4	I	Br
56	W	70	6	15	34	28	0.8	35.4	27.9	3.0	9.9	K	SW
57	B	60	8	16	301	305	1.0	24.1	27.0	3.2	73.5	K	Gr
58	B	51	5	10	67	42	0.6	11.7	29.1	5.0	4.9	I	Br
59	W	50	5	10	73	99	1.4	16.5	26.5	3.5	16.3	K	SW

Appendix A cont...

P. No.	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat colour
60	W	46	3	6	48	54	1.1	28.5	25.3	2.8	15.4	K	SW
61	P	43	2	6	17	19	1.1	23.2	27.5	5.4	4.4	I	Br
62	P	54	5	13	44	38	0.9	30.3	24.6	3.7	11.5	K	Br
63	B	52	3	6	53	48	0.9	20.2	30.5	4.3	9.7	I	Gr
64	P	45	3	8	45	38	0.8	29.7	26.3	3.9	11.3	K	Br
65	P	63	4	6	51	39	0.8	43.1	25.9	3.7	16.8	K	Br
66	P	52	6	13	53	39	0.7	46.9	26.5	3.7	18.3	K	Br
67	P	55	7	20	66	53	0.8	28.1	25.8	3.4	14.9	K	Br
68	P	54	5	10	115	92	0.8	30.4	24.2	3.5	28.0	K	Br
69	P	54	8	20	35	16	0.5	29.4	29.5	4.9	4.7	K	Br bl
70	P	47	3	4	27	16	0.6	44.4	25.3	4.1	7.1	K	Br
71	B	48	4	15	58	43	0.7	13.3	27.6	4.7	5.7	I	Gr
72	B	59	5	15	125	91	0.7	17.8	28.1	3.4	16.2	K	Gr
73	W	53	6	18	60	48	0.8	22.7	26.0	2.9	10.9	K	SW
74	W	59	6	17	75	62	0.8	29.2	25.7	2.9	18.1	K	SW
75	P	63	5	16	125	106	0.8	26.1	23.3	4.9	27.7	I	Br
76	B	49	3	9	47	34	0.7	23.8	25.9	3.2	8.1	K	Gr
77	W	60	4	8	82	48	0.6	32.9	26.7	2.6	15.8	K	SW
78	W	68	5	12	47	44	0.9	24.5	21.6	2.5	10.8	K	SW
79	P	53	4	6	40	40	1.0	28.2	22.6	3.7	11.3	K	Br
80	W	56	4	8	10	20	2.0	26.5	23.5	3.0	5.3	K	SW
81	B	65	5	11	35	30	0.9	20.0	27.8	3.5	6.0	I	Gr
82	P	42	4	6	20	30	1.5	25.7	24.8	5.0	7.7	K	Br
83	P	52	4	8	28	20	0.7	26.5	24.3	4.9	5.3	I	Br
84	B	59	6	14	164	144	0.9	17.1	26.4	4.3	24.6	K	Gr
85	W	59	5	10	51	37	0.7	29.5	26.9	4.3	10.9	K	SW
86	W	50	5	14	27	25	0.9	34.4	23.1	3.6	8.6	K	SW
87	P	55	4	9	12	19	1.6	28.9	21.4	4.8	5.5	I	Br
88	W	50	4	12	54	62	1.1	18.9	22.5	4.3	11.7	K	SW
89	B	53	3	10	25	23	0.9	19.6	25.4	6.0	4.5	I	Gr
90	P	54	4	8	57	93	1.6	20.3	26.4	4.4	18.9	K	Br
91	P	58	6	12	75	50	0.7	20.8	26.5	4.1	10.4	K	Br

Appendix A cont...

P. No.	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat colour
92	W	70	5	12	25	10	0.4	26.0	27.0	4.5	2.6	K	SW
93	P	50	3	9	65	67	1.0	28.8	24.6	4.7	19.3	I	Br
94	P	47	5	11	120	107	0.9	31.6	24.3	5.1	33.8	K	Br
95	P	62	6	10	28	18	0.6	23.3	21.9	5.8	4.2	I	Br
96	P	58	3	5	12	12	1.0	35.8	23.8	5.4	4.3	K	Br
97	P	52	5	12	77	77	1.0	29.6	24.8	5.0	22.8	K	Br
98	W	60	5	10	23	25	1.1	26.8	26.8	4.3	6.7	K	SW
99	W	52	5	12	30	29	1.0	29.0	24.7	5.4	8.4	K	L br
100	W	49	3	6	68	54	0.8	28.7	28.5	3.2	15.5	K	SW
101	P	50	4	12	76	71	0.9	30.8	23.2	4.9	21.9	I	Br
102	W	48	6	14	64	71	1.1	23.5	24.1	3.0	16.7	K	SW
103	B	65	7	19	28	26	0.9	25.0	26.8	3.8	6.5	I	Gr
104	P	50	3	6	89	99	1.1	21.8	26.3	6.2	21.6	I	Br
105	P	58	3	9	55	62	1.1	26.3	26.1	4.5	16.3	I	L br
106	P	50	3	6	26	19	0.7	31.1	28.1	3.8	5.9	K	Br
107	P	53	4	10	50	43	0.9	34.4	25.0	4.0	14.8	K	Br
108	B	60	6	13	34	56	1.6	24.5	25.5	3.2	13.7	K	Gr
109	P	53	5	11	42	28	0.7	18.6	27.3	4.6	5.2	I	L br
110	P	49	4	9	43	45	1.0	22.7	25.4	4.4	10.2	I	Br
111	W	65	5	13	51	33	0.6	37.6	26.5	2.7	12.4	K	SW
112	P	57	4	8	63	50	0.8	23.4	23.1	4.1	11.7	K	Br
113	P	55	6	14	26	29	1.1	27.2	25.3	3.5	7.9	K	L br
114	P	54	5	11	72	77	1.1	24.8	25.6	4.8	19.1	K	Br
115	P	53	5	11	40	39	1.0	29.0	23.6	3.8	11.3	K	Br
116	P	50	10	22	192	200	1.0	28.2	23.5	4.4	56.4	K	Br
117	W	50	5	14	81	91	1.1	25.8	24.6	4.9	23.5	K	Br

P. No. = Plant number; FC = Flower colour; Plht = Plant height; No. Pbr = Number of primary branches per plant; No. Sbr = Number of secondary branches per plant; No. Pods = Number of pods per plant; No. Seeds = Number of seeds per plant; Sdpod = Number of seeds per pod; 100- seed = 100-seed weight; PC = Seed protein content; CF = Crude fibre content; Seed yld = Seed yield per plant; Seed type = Type of seed; Seed coat color = Seed coat colour.

Flower colour : B = Blue; P = Pink; W = White.
Seed type : K = Kabuli; I = Intermediate.
Seed coat colour : SW = Salmon white; L br = Light brown; Br = Brown; Gr = Gray; Br bl = Brown with blackish spot; Bl br = Blackish brown.

APPENDIX B

Individual plant data for various characters studied in F_2 generation of the cross RS 11 x T 39-1, *Rabi* 1997/98.

P. No.	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat color
1	P	40	2	6	81	82	1.0	14.3	23.8	11.6	11.7	D	Br
2	W	49	4	8	179	181	1.0	18.5	25.0	9.8	33.5	D	Y br
3	W	50	3	6	98	70	0.7	7.7	26.8	8.2	5.4	I	Gr
4	W	40	2	5	10	13	1.3	12.3	30.1	0.0	1.6	I	Gr
5	W	48	2	5	33	34	1.0	15.6	24.1	6.9	5.3	I	Br
6	B	57	4	9	94	91	1.0	10.2	26.9	7.9	9.3	I	Br
7	P	50	4	6	30	35	1.2	17.4	23.1	8.6	6.1	D	L br
8	P	48	2	6	33	29	0.9	16.2	25.9	9.9	4.7	D	L br
9	P	53	4	8	40	51	1.3	17.3	22.0	9.3	8.8	D	Br
10	P	51	5	15	132	109	0.8	17.7	22.1	9.4	19.3	D	Br
11	B	59	5	13	158	249	1.6	15.5	23.9	7.4	38.6	I	Br
12	P	53	7	15	57	56	1.0	18.4	24.1	6.6	10.3	I	Gr
13	P	56	3	7	71	71	1.0	15.8	23.4	7.8	11.2	D	O br
14	P	50	5	10	138	85	0.6	10.6	27.8	8.5	9.0	I	Gr
15	B	57	6	18	199	156	0.8	11.2	24.8	7.4	17.5	I	Gr
16	P	49	4	8	49	61	1.2	16.7	27.4	8.5	10.2	D	L br
17	P	51	3	7	57	62	1.1	19.0	26.2	7.9	11.8	I	Gr
18	P	55	5	19	40	55	1.4	17.6	26.2	6.7	9.7	D	Br
19	B	52	3	10	48	52	1.1	10.4	26.3	8.0	5.4	I	Gr
20	W	50	4	8	34	53	1.6	15.3	22.8	6.5	8.1	I	O br
21	P	49	3	6	52	54	1.0	15.6	22.8	6.2	8.4	I	O br
22	B	56	6	20	244	239	1.0	10.1	25.5	7.9	24.1	I	Gr
23	B	50	3	8	63	58	0.9	11.6	27.7	8.6	6.7	I	Gr
24	P	58	5	9	49	64	1.3	17.8	21.7	7.7	11.4	I	D br
25	W	60	3	5	37	30	0.8	10.0	27.7	0.0	3.0	I	Gr
26	P	50	4	6	74	86	1.2	15.6	20.9	9.8	13.4	D	Y br
27	P	57	5	15	55	60	1.1	17.5	23.4	7.7	10.5	D	B
28	P	48	3	10	76	83	1.1	15.1	21.5	7.7	12.5	D	L br
29	P	63	4	8	57	50	0.9	19.6	21.1	8.9	9.8	D	Br
30	B	56	7	14	91	102	1.1	11.1	27.7	8.8	11.3	I	Gr

Appendix B cont....

P. No	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat color
31	P	49	3	5	30	43	1.4	20.5	23.9	9.2	8.8	D	Br
32	B	52	2	4	91	97	1.1	12.1	26.7	7.5	11.7	I	Gr
33	P	48	4	7	24	47	2.0	14.9	21.4	7.5	7.0	D	L br
34	B	57	6	10	73	51	0.7	13.3	25.1	7.1	6.8	I	Gr
35	B	59	8	16	82	55	0.7	9.1	26.8	8.7	5.0	I	Gr
36	B	55	6	10	45	48	1.1	22.3	22.5	9.1	10.7	D	Br
37	B	58	7	17	87	100	1.1	11.0	25.2	7.7	11.0	I	Gr
38	B	43	4	10	72	61	0.8	9.8	25.3	6.9	6.0	I	Br
39	P	52	5	11	54	69	1.3	15.2	20.5	7.0	10.5	I	O br
40	P	54	7	13	35	62	1.8	16.1	21.7	8.7	10.0	D	Br
41	P	64	6	11	117	124	1.1	16.6	22.1	8.9	20.6	D	Br
42	P	60	3	7	71	66	0.9	17.9	21.7	8.0	11.8	D	Br
43	W	50	5	10	38	41	1.1	18.3	23.6	8.0	7.5	D	Br
44	B	54	6	12	104	75	0.7	12.1	26.0	8.3	9.1	I	Gr
45	W	46	5	10	60	60	1.0	17.2	22.6	9.4	10.3	D	Br
46	P	63	4	13	61	79	1.3	16.5	24.1	8.2	13.0	D	L br
47	P	50	4	8	61	50	0.8	14.6	26.5	7.1	7.3	I	O br
48	P	46	6	12	72	74	1.0	16.6	22.8	7.6	12.3	D	Br
49	P	45	2	4	45	38	0.8	16.6	20.6	10.9	6.3	D	Br
50	B	57	7	12	78	145	1.9	10.0	25.4	7.8	14.5	I	Gr
51	P	55	6	11	84	71	0.8	18.0	23.4	8.2	12.8	D	L br
52	P	45	5	10	55	69	1.3	17.8	24.4	8.1	12.3	D	Y br
53	B	49	8	14	69	71	1.0	10.0	27.2	7.7	7.1	I	Gr
54	P	45	4	8	48	48	1.0	19.0	24.2	8.9	9.1	D	Br
55	P	45	4	15	96	104	1.1	15.1	24.1	7.2	15.7	I	Br
56	P	55	6	9	112	169	1.5	16.2	23.5	9.1	27.3	D	L br
57	P	50	4	11	43	41	1.0	19.8	24.3	8.7	8.1	D	Br
58	P	55	4	11	61	52	0.9	17.7	22.0	8.5	9.2	D	Br
59	P	53	4	9	90	102	1.1	15.9	22.6	9.3	16.2	D	Br
60	P	44	7	14	65	73	1.1	13.8	24.0	11.0	10.1	D	Y br
61	W	47	4	10	72	93	1.3	14.2	23.6	9.4	13.2	D	Br
62	B	57	6	16	160	215	1.3	10.8	25.7	8.4	23.3	I	Gr
63	P	50	3	12	60	66	1.1	13.6	24.8	9.6	9.0	D	Br
64	P	46	4	9	29	27	0.9	19.6	22.5	8.6	5.3	D	Br

Appendix B cont....

P. No.	FC	Plht (cm)	No. Pbr	No. Sbr	No. Pods	No. Seeds	Sdpod	100-seed (g)	PC (%)	CF (%)	Seed yld (g)	Seed type	Seed coat color
65	P	40	4	9	49	53	1.1	17.9	23.2	9.9	9.5	D	L br
66	B	47	4	11	70	92	1.3	9.8	26.0	9.3	9.0	I	Gr
67	P	49	5	12	88	109	1.2	15.5	21.2	9.3	16.9	D	Br
68	P	45	4	12	120	145	1.2	16.6	22.2	9.4	24.1	D	Br
69	P	43	3	7	83	90	1.1	18.2	23.4	9.0	16.4	D	Y br
70	P	50	5	14	117	133	1.1	14.4	23.5	10.1	19.1	D	Br
71	P	50	5	13	92	87	0.9	17.9	22.6	8.5	15.6	D	Br
72	B	55	4	6	58	70	1.2	11.1	25.3	8.0	7.8	I	Br
73	P	44	2	4	87	102	1.2	14.0	21.7	9.3	14.3	D	Br
74	P	43	4	8	39	39	1.0	14.4	25.3	10.0	5.6	D	Br
75	P	52	4	12	103	167	1.6	14.4	26.1	8.7	24.1	I	L br
76	B	54	6	14	142	104	0.7	9.2	28.4	8.4	9.6	I	Gr
77	P	50	6	10	88	122	1.4	15.2	23.7	8.3	18.5	D	Y br
78	P	60	9	19	203	219	1.1	19.0	23.6	8.7	41.6	D	Br
79	W	53	4	12	124	163	1.3	11.7	28.9	6.4	19.1	I	Gr
80	W	48	3	6	55	84	1.5	12.6	23.8	11.4	10.6	D	Br
81	P	56	4	8	40	52	1.3	18.7	24.8	10.5	9.7	D	Br
82	P	58	4	13	106	103	1.0	18.2	23.6	7.9	18.7	I	O br
83	B	50	4	8	53	60	1.1	8.3	26.6	7.3	5.0	I	Br
84	P	55	5	10	53	62	1.2	14.4	25.0	9.6	8.9	D	Y br
85	P	52	4	8	100	130	1.3	15.8	22.6	10.0	20.5	D	Br
86	P	50	3	13	63	74	1.2	18.9	21.7	8.4	14.0	D	L br
87	B	54	4	8	106	77	0.7	10.5	27.0	7.6	8.1	I	Gr
88	P	61	4	8	45	51	1.1	18.6	21.6	9.1	9.5	D	Br
89	P	60	4	10	47	35	0.7	17.1	26.0	9.2	6.0	D	L br
90	B	56	4	13	165	154	0.9	9.1	27.6	5.2	14.0	I	Br

P. No. = Plant number; FC = Flower colour; Plht = Plant height; No. Pbr = Number of primary branches per plant; No. Sbr = Number of secondary branches per plant; No. Pods = Number of pods per plant; No. Seeds = Number of seeds per plant; Sdpod = Number of seeds per pod; 100-seed = 100-seed weight; PC = Seed protein content; CF = Crude fibre content, Seed yld = Seed yield per plant; Seed type = Type of seed; Seed coat color = Seed coat colour.

Flower colour : B = Blue; P = Pink; W = White.
Seed type : D = Desi; I = Intermediate.
Seed coat colour : Y br = Yellow brown; O br = Orange brown; L br = Light brown; Br = Brown; Gr = Gray; D br = Dark brown.

APPENDIX C

Weather data during the crop growth period (October 14- March 3, 1997/98).

Standard week	Rainfall(mm)	Evaporation (mm)	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity at 0717 hr (%)	Relative humidity at 1417 hr (%)	Wind velocity (km/hr)	Sun shine hours	Solar radiation (mj/m**2/d)
42	0.0	34.3	31.3	20.0	88.4	46.7	4.9	8.1	18.2
43	4.2	30.9	30.0	19.8	92.0	53.3	7.3	6.8	14.9
44	52.2	27.1	29.5	19.8	94.9	71.3	7.4	7.4	15.3
45	0.9	28.6	29.7	17.9	91.6	48.7	4.8	7.5	16.7
46	46.6	23.5	29.0	19.8	96.3	62.4	5.1	5.0	13.0
47	0.0	27.1	29.0	19.8	91.0	58.4	8.0	8.0	15.0
48	3.5	30.9	29.2	20.4	90.7	57.9	9.0	7.9	15.2
49	25.0	28.5	28.1	18.1	93.6	52.4	10.6	7.0	14.5
50	0.7	18.1	26.9	17.1	93.0	63.6	6.5	6.9	13.5
51	2.5	18.4	27.5	18.7	95.7	59.9	8.4	5.5	11.9
52	0.0	32.4	29.4	17.6	95.0	43.3	7.8	8.1	16.3
1	0.0	29.7	27.8	14.0	94.3	42.7	5.8	9.0	15.9
2	0.0	26.5	28.4	12.5	97.4	39.9	3.8	9.5	17.3
3	0.0	32.4	31.3	15.8	93.1	42.4	7.1	9.0	16.5
4	0.0	34.9	30.5	17.9	88.7	40.9	10.5	9.0	17.4
5	0.0	35.6	30.9	18.0	93.1	41.0	8.4	8.8	17.5
6	0.0	37.9	30.4	17.1	83.0	38.7	7.9	8.3	17.1
7	0.0	43.6	31.1	15.7	79.1	33.9	6.4	9.7	20.5
8	0.0	47.7	33.1	15.8	74.4	24.9	6.4	10.2	21.6
9	29.6	51.2	34.3	19.3	81.3	31.4	7.3	9.4	20.8