INHERITANCE OF STEM PIGMENTATION AND FLOWER COLOUR IN CHICKPEA (*Cicer arietinum* L.)

BY

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CERTIFICATE

Mr. KIRAN KUMAR V.S.S., has satisfactorily prosecuted the course of research and that the thesis entitled " **INHERITANCE OF STEM PIGMENTATION AND FLOWER COLOUR IN 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 him for the degree of any university.

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Date 22-10-2001

Place Hyderabad

CERTIFICATE

This is to certify that the thesis entitled "**INHERITANCE OF STEM PIGMENTATION AND FLOWER COLOUR IN CHICKPEA** (*Cicer arietinum* L.) " is submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. KIRAN KUMAR V.S.S** 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 for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.

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ABSTRACT

An investigation was carried out during post rainy season of 2000-01 at ICRISAT Asia Center Patancheru, to study the inheritance of stem pigmentation and flower colour, to determine different genotypes white flower colour and to study the associations among the important traits in chickpea.

To study the inheritance of stem pigmentation and flower colour ICC 5716 and ICC 17101 were used as parents in which ICC 5716 was with high pigmented stem and pink flower and ICC 17101was with low pigmented stem and white flowered. Inheritance studies were made to study stem pigmentation, flower colour and association studies for different quantitative characters.

Monogenic inheritance was confirmed for the two morphological characters i.e. low pigmented vs. high pigmented and pink flower colour *vs.* white flower colour. Low stem pigmentation dominated high stem pigmentation character and fits well to the expected ratio 3:1. Pink flower colour dominated the white flower colour and fits well to the expected ratio 3:1. Joint segregation of these two characters showed independent assortment and fits well to the expected ratio 9:3:3:1 indicating that these two characters are controlled by two different genes. The results of F_2 generation were confirmed in the study of F_3 generation.

In both F_2 and F_3 generations yield per plant was correlated with plant height and with number of pods per plant, number of seeds per plant and number of secondary branches per plant. In F_2 generation number of primary branches per plant and in F_3 generation days to maturity and hundred seed weight were not associated with any of the characters studied. Number of seeds per plant in both F_2 and F_3 generations positively correlated with plant height, number of secondary branches per plant, plant width, and yield per plant.

In determining different genotypes for white flowered type, ICCV 2, RS 11 (white flowered) and T 39-1, T-1-A (blue flowered) were used as parents. Cross between the white and blue flowered parents (ICCV 2 x T-1-A and RS 11 x T 39-1) their F_1 was pink flower in both cases and their F_2 generation segregated as pink, blue and white, fits well to the ratio of 9:3:4 indicating supplementary gene action. The genotypes for the parents were determined as ICCV 2 *CCbbPP*, T-1-A *CCBBpp*, F_1 pink *CCBbPp*, F_2 pink *C-B-P-*, F_2 blue *C-B-pp* and F_2white flower *C-bbP-* and *C-bbpp*. Genotypes of RS 11 *ccBBPP*, T 39-1 *CCBBpp*, F_1 pink *CcBBPp*, F_2 pink *C-B-P-* F_2 blue *C-B-pp*, F_2white *ccB-P-* and *ccB-pp*.

By intercrossing the above mentioned white flowered genotypes {(ICCV 2 x T-1-A F_2 white flower) **x** (RS 11 x T 39-1 F_2 white flower)} in F_1 pink and blue flower were resulted, in F_2 pink flower segregated into pink, blue and white (9:3:4 supplementary gene action), blue flower segregated into blue and white (9:7 complementary gene action). In both cases white flowers were resulted and their genotypes were fixed as were *C-bb P-* *cc B-P-* *ccBb pp* *C-bbpp* *ccbbP-* *ccbbpp*. In this study a tripple recessive genotype for white flower i.e., ***ccbbpp*** was determined for the first time.

Among different white flower genotypes yield per plant, showed a non significant association with all the traits under study except with, number of pods per plant. Number of pods per plant positively correlated significantly with plant height, number of secondary branches, number of seeds per plant, plant width and yield per plant.

DECLARATION

I, **KIRAN KUMAR V.S.S** hereby declare that the thesis entitled **"INHERITANCE OF STEM PIGMENTATION AND FLOWER COLOUR IN 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. I also declare that the thesis or part thereof has not been published earlier elsewhere in any manner.

Date: 22.10.01
Place: Hyderabad

(KIRAN KUMAR V.S.S)

LIST OF ABBREVIATIONS

100-seed weight	HSW
Centimeter	cm
Chi-square	χ^2
Days to 50% flowering	DF50%
Days to first flowering	DFF
Days to first pod formation	DFP
Days to maturity	DM
Flower colour	FC
Grams	g
Hectare	ha
Million Tonnes	MT
Number of pods per plant	NPP
Number of primary branches per plant	Pb
Number of secondary branches per plant	Sb
Number of seeds per plant	NSP
Plant height	Ht
Plant width	Wd
Probability	p
Stem pigmentation	SP
Yield per plant	Yld_P

Introduction

CHAPTER I

INTRODUCTION

Food legumes play a major role in agriculture because they are an important source of food and capable of fixing atmospheric nitrogen through their association with *Rhizobia* bacterium consequently they can be grown in soils of low fertility, and they are referred to as mini fertilizer factories They utilize soil moisture efficiently because of their long roots and have capacity of yielding something even under marginal and most neglected conditions and with low inputs Thus they enhance soil fertility and can be grown on conserved residual soil moisture They also improve soil physical structure

The world pulse production and consumption is dominated by the Indian subcontinent the Middle East including the Mediterranean region India is the major pulse growing country in the world sharing 35 9 % area and 27 % production (FAO 2000)

Chickpea (*Cicer arietinum* L) is called Bengal gram or gram in India and garbanzo bean in much of the developed world It is the world's third most important food legume crop in terms of consumption and by far the most important pulse in South Asia The versatility of chickpea in cuisine is legendary (Vander maesen 1972) Chickpea is currently grown on about 12 03 m ha worldwide in which India has a share of 69 8% with 8 4 m ha It ranks first with a share of 72 8% in the world production The productivity of chickpea is low as compared to cereals, since chickpeas are generally grown in poor-soils and drought-prone, environments. The world's mean productivity is 768 kg/ha. India's productivity is 798 kg/ha (FAO, 2000).

Selection plays a vital role in success of a breeding programme, which depends upon the nature and magnitude of association between characters. So, to find out the association, correlation is a tool, which can be used to identify the useful characters influencing yield and undesirable associates between the component characters. This emphasizes the importance of correlation studies.

The use of markers in a crop cultivar gives an added advantage in characterizing, selection and in maintaining the genetic purity. Several morphological markers for shape, colour, size, and pigmentation are used in different crops. Flower colour and stem pigmentation are useful morphological markers in chickpea. Genetics of various flower colours of chickpea is not well understood as also for many other traits. The available information on markers and traits and their linkage is rather limited. Hence the present study is conducted with the following objectives.

1. To investigate the inheritance of stem pigmentation and flower colour,
2. To determine different genotypes for white flower colour, and
3. To investigate association among important traits.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Review of literature pertaining to inheritance of stem and flower pigmentation, flower colour and correlation among different traits in chickpea (*Cicer arietinum* L.) is presented briefly under the following headings:

2.1 Inheritance of stem and flower pigmentation.

2.2 Inheritance of flower colour.

2.3 Associations among important traits (Correlation coefficients).

2.1 INHERITANCE OF STEM PIGMENTATION AND FLOWER COLOUR

The stem and flower pigmentations in chickpea are useful morphological markers.

Bhapkar and Patil (1962) found that foliage and flower colour are governed by a single factor and also reported that the seed coat colour was controlled by two complimentary factors. They further pointed out that the factor responsible for foliage colour was different and independent from the factors responsible for flower and seed coat colours.

Aher and Patil (1984) studied the colours of stem axil, pedicel, corolla and veins on the ventral surface of the standard petal. He reported that all these traits are controlled by a single pleiotropic gene; *Lvco*. This gene is independent of the genes *Brsco* and *Ysco* that control seed testa colour.

Nasu and Bhat (1984) found that colours of stem and corolla in cotton were controlled by two genes and one gene and that the red pigmentation was dominant in stem, boll and bract and incompletely dominant in the corolla.

Ghatge and Kolhe (1985) reported that pink *vs* white colours of stem, pedicel, sepal, petal and petal vein were found to be governed by genes at two loci, *Wcoa* and *Wcob* with pleiotropic action and these colours showed an F_2 segregation ratio of 9:7.

Essomba *et al.* (1987) who studied F_2 complete diallel cross of peanut suggested that purple and green pigmentation were controlled by at least one and two duplicate genes and epistatic and/or additive effects exist for growth and inter nuclear factors influence relationship between traits.

The stem pigmentation depends upon presence or absence of anthocyanin pigment, which is light dependent. Mathur (1989) reported a chickpea line, which developed purple pigmentation in the whole plant, stem, branches, leaves and flowers and concluded that this purple pigmentation is utterly light dependent. He reported that these plants do not produce pigmentation if not directly exposed to sunlight.

Kabir and Sen (1991) found that anthocyanin pigmentation of the stem is controlled by two genes, one of which showed partial dominance and was epistatic to the other gene in the recessive homozygous state.

Karkannavar *et al.* (1991) proposed digenic inheritance of stem pigmentation with complementary gene action and a 17.4 % crossover was seen between one complementary gene for stem pigmentation and the gene for stipule colour.

Metz *et al.* (1992) studied inheritance of purple seedling colour (PSC) and its relation to genetic control of flower colour. It was found that PSC is probably controlled by a single gene. They further observed that this trait is dominant over green seedling colour. The white flower inhibited the expression of PSC and was therefore thought to be epistatic.

Ahmed and Tanki (1992) reported the partial dominance of purple stem over green stem in chilli and observed continuous variation in F_2 and the back cross generations indicated polygenic control of anthocyanin pigmentation.

Sandhu *et al.* (1993) obtained 13 green foliage and 3 purple foliage in F_2 after crossing purple pigmented plant as male with normal green foliage. They suggested digenic inheritance of colour with dominant and recessive epistatis in F_1 normal green foliage is dominant over purple foliage thus the plants with *P-I-/ ppI- / P-ii* genotypes have green foliage and those with the *P-ii* genotype have purple foliage.

Singh *et al.* (1993) studied F_1, F_2 and F_3 generations by using two pigeonpea varieties and five ICP lines. The two ICP lines ICP11204 and ICP 8862 had purple stems and remaining are of green. All F_2s segregated in the ratio 3 purple : 1 green. F_3 produced 1 purple : 2 segregating : 1 green, suggesting that stem pigmentation is controlled by a single gene with purple as dominant.

Ghatge (1993) studied the crosses in chickpea revealed that cotyledon colour was controlled by a single gene (*Ycot*), white foliage colour was due to *Ycot* and *Blgfo*.

Ghatge (1994a) indicated that purple stem colour is dominant over green stem colour and pink corolla dominant over white. The genes governing the inheritance of stem colour and corolla colour are designated as P_{st} and B_{co} and B_{co} and P_{co} respectively with B_{co} being common to both traits.

Joshi *et al.* (1994) reported the existence of a basic pleiotropic gene (*Pl*) responsible for the expression of pigmentation of axil, calayx, corolla, pod tip and seed together with localizing genes conditioning colouration on specific plant parts in cowpea.

Ahmad (1997) indicated that the stem colour is determined by the interaction of three pairs genes namely *P-P*, *I-i* and *R-r*. *P-p* (green pigmentation), *I-i* (colour intensity) and *R-r* (pigment reduction) in kenaf.

Pundir and Reddy (1997) reported a natural mutant which combines purplish stem (low pigmented) with white flower. This trait combination was not previously known in *Cicer* and designated this mutant as ICC 17101.

Mathur (1998) analysed the light-dependent purple pigmentation and suggested complimentary interaction of two genes (9:7) for light dependent purple (*LDP*) and non-*LDP* pigmented plants by using ICC 32 and ICC 10301 parents.

Venugopal and Goud (1998) reported from the segregation analysis that all pigmented characters were dominant over non-pigmented characters in cowpea. The F_2 phenotypic ratios of 11:5 (two threshold dominant genes), 9:7 (two complimentary genes), 3:1 (monogenic dominant), 11:5 (two threshold dominant genes) 15:1 (two duplicate genes) and 54:10 (any two of the complimentary genes) were observed for pigmentation on secondary and tertiary branches, pulvinus, stalk tip, peduncle surface, peduncle tip and stipules respectively.

Tefera (1998) confirmed monogenic inheritance for three morphological characters pink *vs* white flowers, pigmented *vs* non pigmented stem colours, and single podded *vs* double podded characters. The flower colour of genotype ICCV 2 was determined as *PPbbCC* and JG 62 as *PPBBCC*. This gene was found to have pleiotropic effect as it controlled the stem colour as well.

Sabaghpour (2000) studied the interrelationships between pairs of characters such as: flower colour, stem colour, seed coat colour. He observed that the gene *b* controlling the flower colour had a pleiotropic effect on stem colour suggesting monogenic inheritance of flower colour patterns in chickpea.

Single gene inheritance model was proposed by Metz *et al.* (1992), Ghatge (1993), Singh *et al.* (1993) and Tefera (1998), digenic inheritance model was proposed by Ghatge and Kolhe (1985), Mathur (1989), Kabir and Sen (1991), Sandhu *et al.* (1993), Nasu and Bhat (1984) and trigenic model was proposed by Ahmed (1997) and polygenic inheritance was proposed by Ahmed and Tanki (1992). From the above mentioned studies the stem and flower pigmentation in chickpea are reported to be monogenic, digenic or trigenic. Thus at least three genes govern the stem pigmentation and flower colour in chickpea.

2.2 INHERITANCE OF FLOWER COLOUR

In chickpea, there are three distinct flower colours namely pink, blue and white. Two white flowered varieties P 9623 and RS 11 when crossed produced pink flowered hybrid indicating the presence of different genes controlling their flower colour (Kumar, 1997). 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.

They reported that the blue colour was due to a single factor *B*; a factor *P* gave pink colour in the presence of *B* but was by itself without colour effect. 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 the flower colour was governed by 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.

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 colour was dominant to white flower. They obtained pink and white flower segregation in the ratio of 3 : 1

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.

D'Cruz and Tendulkar (1970) showed from F_1 and F_2 generations of the cross Double pod x White flower White grain 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.

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.

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) studied 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.

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 dominance 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 genes for filiform leaf trait *fil* and w_2 were linked.

Stephens and Nickell (1992) found a new flower colour pink in soybean, on selfing the pink flower colour is controlled by a single recessive gene, when crossed with all reported flower colour genes, the pink flower gene (*WP*) is independent of a known flower colour genes and acts on modified gene.

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.

Raini *et al.* (1994) reported that growth habit flower colour, pod colour, pod shape and seed colour are each controlled by two genes. Singh *et al.* (1994) studied F_1, F_2 and F_3 of pigeonpea crosses and suggested that red purple flower colour was governed by a single gene with complete dominance over yellow colouration.

Singh *et al.* (1994) indicated that red purple flower colour was governed by a single gene with incomplete dominance over yellow colouration that pod colour was governed by a single gene with complete dominance.

Singh and Singh (1995) found that the F_1 progeny of the violet x white crosses had violet flowers, and in the F_2 the ratio of violet to white flowers was 3: 1 suggesting that violet flower colour was governed by single dominant gene.

Dwivedi *et al.* (1996) reported in groundnut an unstable white flower colour from the cross between two yellow flowered parents and concluded that the probably source for this inconsistent segregation for flower colour is the presence of an unstable genetic element along with the alleles producing white flower phenotype.

Venugopal and Goud (1996) reported from F_1 and F_2 the calyx pigmentation was controlled by three duplicate genes in cowpea. Violet flower colour was dominant over light violet and was controlled by two complementary genes.

Biradar *et al.* (1997) reported the involvement of three genes for calyx pigmentation (*Ptc, Pt, Pc*) and seed coat pigmentation (*Pf,* P_1, P_2) and four genes for pod tip pigmentation (*Ptc* $P_1P_2P_3$) and flower colour (*Pt* P_1 P_2 P_3) in the crosses they studied.

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.

Vijayalakshmi (1998) studied the inheritance of flower colour and reported three different genes governing flower colour, and supplementary type of gene action was observed in the two crosses studied and designated genotype for white flower colour is *CCbbPP*, for pink *CCBbPp* and for blue *CCBBpp*.

Kumar *et al.* (2000) reported supplementary type of gene action for flower colour based on segregation for two independent loci by crossing white flower coloured female parents with blue flowered male parent.

Sabaghpour (2000) monogenic inheritance obtained for the character, pink *vs* white flowers, and determined the genotype of ICCV 2 as *PPbbCC* and of JG 62 as *PPBBCC*. He also suggested that the seed coat colour is controlled by three pairs of genes but some of them were different than for flower colour.

Gaur and Gour (2001) reported that a recessive gene, designated *ifc*, was found to inhibit flower colour without affecting vein colour of corolla. When *ifc* present in homogygous condition, *P-B-* and *ppB-* genotypes gave pink-veined white flower and blue veined white flowers, respectively.

From the above studies, the inheritance of flower colour is reported to be monogenic, digenic and trigenic. Biradar *et al.* (1997) proposed 4-gene inheritance model for flower colour. 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), Vijayalakshmi (1998) and Gaur and Gour (2001) 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), Patil and Deshmukh (1975), Reddy and Chopde (1977), Pawar and Patil (1979), Rao *et al.* (1980) and Raini *et al.* (1994), 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 the other workers have proposed monogenic inheritance model. The gene symbols used by them namely *Bco*, *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.

It is apparent that the flower colour in chickpea is controlled by more than three gene pairs. The seed coat colour is also governed by more than three genes. At least one gene for flower and seed coat colours is common. As we conduct more research more genes will be identified. This is expected because the related species with which chickpea shares considerable synteny *Pisum sativum*, has many more genes identified for this and other traits.

2.3 Correlation coefficients

Correlation coefficient is an important statistical tool for determining association between two characters. Understanding of the inter-relationship between seed yield and its components and among the components themselves is necessary to improve seed yield since it is a complex character. A review of literature for correlations of yield with yield contributing traits is given as follows.

Reddy and Rao (1988) analyzed 50 F_2 chickpea populations derived from inter varietal 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 association with yield.

Sharma and Maloo (1988) observed in 21 chickpea varieties that the grain yield was significantly correlated with number of pods per plant for two planting dates (i.e. 28 November and 14 December) (r = 0.7 and r = 0.7, respectively), with the number of primary branches per plant (r = 0.5) and 100-seed weight (r= 0.7) for earlier planting dates. They also reported that days to flowering showed strong positive correlation with days to maturity, and days to maturity exhibited negative and significant correlation with 100-grain weight in case of second sowing at both genotypic and phenotypic levels.

Salimath and Bahl (1986), Sandhu *et al.* (1988), Mishra *et al.* (1988), Singh *et al.* (1989), Sandhu *et al.* (1989), Sandhu and Mandal (1989) and Tagore *and* Singh (1990) carried out association studies and reported significant positive association of seed yield with primary branches per plant, secondary branches per plant and pods per plant and suggested selection for these characters to improve yield.

Sandhu and Mandal (1989) from their studies in 48 diverse chickpea lines observed that seed yield was positively correlated with primary and secondary branches, pod number and seed number.

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 of flowering, late maturity and large grain mass white selecting genotypes for grain yield.

Uddin *et al.* (1990) investigated correlation derived from the data of 54 genetically diverse chickpea lines and reported that yield per plant had significant positive correlations with pods per plant, 100-seed weight and primary branches per plant.

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.

Bhambotha *et al.* (1994) evaluated 32 genotypes in four different environments, and their correlation analysis revealed positive associations between pod bearing branches per plant, pods per plant and plant height with seed yield. Days to maturity had a non-significant correlation with yield in all four environments.

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.

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.

Abdali (1992) worked out correlations on F_4 and F_3 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 in 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.* (1994) 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 40 *Cicer arietinum* genotypes and observed that seed yield per plant was positively associated with pods per plant, plant height and weight from the data on 10 yield and growth characters in variety PG 5.

Sarvaliya and Goyal (1994) studied 76 chickpea genotypes and revealed significant association between yield and 100 seed weight, plant height, number of primary branches per plant, number of pods per plant, days to maturity and days to flowering at genotypic and phenotypic levels.

Rao *et al.* (1994) studied 44 varieties of *C. arietinum* and reported that seed yield was positively correlated with primary branches, secondary branches, 100-seed weight and pods per plant.

Singh and Rheenen (1994) crossed JG 62 and MS 24 and evaluated along with their F_1 and F_2 and backcross progenies and observed that number of seeds per pod was positively correlated with seed yield in segregating generations ($r = 0.18$).

Bhattacharya *et al.* (1995) studied the association of yield and yield components under soil moisture stress and non-stress environmental in chickpea by taking twelve genetically different chickpea genotypes and reported that, under non-stress conditions, seed yield is mainly influenced through extent of biological yield followed by effective node number per plant and number of seeds per plant, while under stress conditions maximum association was observed for biological yield followed by plant height, harvest index and days to 50 % flowering.

Khorgade *et al.* (1995) based on yield correlation derived from data on nine characters in 30 chickpea genotypes grown under normal and late sown conditions, reported that seed yield showed positive significant association 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 both conditions.

Sandhu and Mangath (1995) studied 32 diverse genotypes of chickpea and found yield per plant showed significant positive association with primary branches, pods per plant and harvest index and negative associations with plant height (45 days after sowing) and days to flowering.

Mathur and Mathur (1996) showed significant positive correlation of grain yield per plant with pods per plan and 100 grain weight but negative correlation with plant height in 34 chickpea varieties.

Ozdemir (1996) reported that number of pods per plant had a significant and positive correlation with seed yield, although it had a negative direct effect, its indirect effect was positive via seed number and seed yield per plant.

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

Chand and Singh (1997) studied 49 genotypes and observed that grain yield per plant had significant positive correlation with number of pods per plant and seeds per plant It was observed that number of pods per plant and seeds per plant are the most yield contributing characters in chickpea

Vijayalakshmi (1998) studied two crosses of chickpea and reported positive correlation with number of pods and seeds per plant, number of primary and secondary branches per plant and seeds per plant also influenced the seed yield directly or indirectly

Or *et al* (1999) studied the phenotypic correlations between days to first flower, pod number and mean grain weight among F_2 populations derived from crosses between early flowering (desi) x late flowering (kabuli) cultivars and revealed a strong association in the characters studied

Sabaghpour (2000) reported that the number of secondary branches per plant, number of pods per plant, seed yield per plant and number of seeds per plant exhibited high correlated response to selection with yield per plot

Raghu (2001) observed that yield showed high positive association with days to first flowering and a negative association with days to 50 % flowering, days to maturity in F_7 generation of chickpea. In F_8 generation of the cross, yield per plant exhibited a non-significant correlation with all the parameters under study excepting the node number, wherein yield showed positive association with node number.

From the above review, almost all cases number of pods per plant, number of primary and secondary branches showed positive correlation with seed yield. Correlation of seed yield with plant height, 100 seed weight and seeds per pod were positive in some studies while negative in other studies. It is easier to measure yield than to measure the number of pods, and secondary branches. It could be said that a visual measurement of pod number could be more efficient.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present investigation was undertaken to study the inheritance of stem pigmentation and flower colour, and to determine the genotypes of different segregants with white flower colour and to determine the association among important traits in chickpea.

The experiment was conducted during the post-rainy season 2000-01 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru, A.P. It is located at an altitude of 545 m above mean sea level, latitude 17°32' N and longitude 78°16' E. The weather data during the crop growth period is given in Appendix 5. The research material was provided by the Chickpea GREP Unit ICRISAT. The details of the materials and methods followed in this experiment are furnished hereunder.

3.1 MATERIALS

The experiment was conducted with six different genotypes involved in three crosses. The parents used were: ICC 5716, ICC 17101, T-1-A, T 39-A, ICCV 2, and RS 11.

During 1999, a chickpea accession ICC 5716 with highly purple stem and pink flower colour was crossed to ICC 17101 with low stem pigmentation and white flower colour. The resulting F_2 produced plants of four types *i e*, high pigmentation with white flower colour, high pigmentation with pink flower colour, low pigmentation with white flower colour and low pigmentation with pink flower colour. These four phenotypes were planted to investigate the inheritance of stem pigmentation and flower colour. For the stem pigmentation and flower colour studies, both parents *i e*., ICC 5716 and ICC 17101 and 151 F_2 plant seeds were used for planting.

The remaining four genotypes were used to determine the different genotypes for white flower. ICCV 2 and RS 11 have white flower colour and I-1-A and T 39-1 are blue coloured types. Crosses were made between (ICCV 2 **x** T-1-A) and (RS 11 **x** T 39-1) during 1997 *rabi* season in the glass house. The two resulting F_1's produced pink flower colour. The F_2 generations of these crosses exhibited three types of flower colour; pink, white and blue. The white flower coloured plants from the F_2 of ICCV 2 **x** T-1-A were crossed with the white coloured F_2 plants of RS 11 **x** T 39-1 in the 1998 *rabi* season. And one reciprocal cross was made. The F_1 of these crosses resulted in pink and blue flowers and in F2 pink blue and white were resulted. From these three types only white flower colour plant seeds were used as planting material in the 2000/01 *rabi* season, a total of 146 white flower plant seeds, 4 parents and 6 selfed white flower seed of previous cross were used as planting material.

3.2 METHODS

The above mentioned chickpea planting materials of two sub experiments were sown during the post rainy season (*rabi*) 2000-01 at ICRISAT research farm Patancheru on 20 October, 2000 on deep vertisol type soils under conserved soil moisture conditions. The plots were single row 2 m long with 60 cm between rows. The seed to seed spacing was 10 cm. There were 156 plots. Alpha design was used for these experiments with two replications. In both the cases sowing was done with the help of planter. All necessary cultural operations and plant protection measures were done to raise a healthy crop.

3.3 COLLECTION OF DATA

In stem pigmentation and flower colour study, both stem pigmentation and flower colour and in the determination of the of different genotypes for white flower colour study the flower colour was recorded after full blooming for each plot. Days to first flower, days to first pod, days to 50 % flowering and days to maturity were recorded on the average performance of plot basis. Single plant data on yield and yield contributing characters were also taken from those selected plants in both cases.

3.3.1 Initial plant stand (IPS)

The total number of plants at germination (about 10 days after sowing).

3.3.2 Flower colour (FC)

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

3.3.3 Stem Pigmentation (SP)

The stem pigmentation was observed at 25 days after sowing as high, low or no pigmentation.

3.3.4 Plant height (Ht)

Height of the plant in centimeters was measured and recorded from the soil surface to the top of the longest branch at the time of maturity for each selected plant.

3.3.5 Plant width (Wd)

Top canopy width in centimeters was measured and recorded for each selected plant.

3.3.6 Number of primary branches per plant (Pb)

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

3.3.7 Number of secondary branches per plant (Sb)

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

3.3.8 Number of pods per plant (NPP)

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

3.3.9 Number of seeds per plant (NSP)

Total number of seeds obtained after threshing of all pods of a plant was counted and recorded. Ill filled seeds and broken seeds were rejected.

3.3.10 Weight of 100 seed (HSW)

Weight of 100 seed was recorded in grams and was obtained by the formula

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

3.3.11 Seed yield per plant (Yld_P)

All the seeds from each plant were weighed with the help of Mettler's electronic weighing machine and recorded in grams.

3.4 STATISTICAL ANALYSIS

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

3.4.1 χ^2 test of good ness of fit

This is a test of statistical significance that is used to test the significance of difference between observed and expected values and also to test the validity of segregation rated for detection of linkage and study of genctics. The χ^2 test was also used to test the presence of linkage.

3.4.2 Correlation coefficients

Correlation refers to the degree and direction of association between two or more than two variables. Correlation coefficient measure the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement of yield.

Simple correlation coefficient among yield and yield contributing traits were worked out using the formula suggested by Panse and Sukhatme (1967).

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

where;

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

σ xy = mean product movement (or) the covariance between x and y

σ x = standard deviation of x

σ y = standard deviation of y

d x Σdy = deviations

$$\sigma\, x = \frac{\sqrt{\sum f\, dx2}}{N} \qquad \sigma\, y = \frac{\sqrt{\sum f\, dy2}}{N}$$

Significance of the correlation coefficient

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

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

Table 1 : Characters of parents used for determination of different white flower Genotypes

Character	ICC V2	RS 11	T 39 – 1	T-1-A
Genotype	*CCbbPP*	*ccBBPP*	*CCBBpp*	*CCBBpp*
Flower colour	White	White	Blue	Blue
Growth habit	Erect	Semi erect	Semi erect	Spread
Seed type	Kabuli	Desi	Intermediate	Intermediate
Seed shape	Owl's head	Angular	Pea	Pea
Duration	Very short	Medium	Long	Medium
Pod size	Large	Medium	Small	Small

Results

CHAPTER IV

RESULTS

During the post-rainy season of 2000-01 an experiment was conducted at ICRISAT Patancheru, near Hyderabad, Andhra Pradesh, to study the inheritance of stem pigmentation and flower colour, and to determine the association among the important traits. Data were recorded on days to first flowering (DFF), days to first pod formation (DFP), days to 50% flowering (DF50%), days to maturity (DM), flower colour (FC), stem pigmentation (SP), Plant height (Ht), plant width (Wd), number of primary branches per plant (Pb), number of secondary branches per plant (Sb), number of pods per plant (NPP), number of seeds per plant (NSP), yield per plant (Yld_P), and 100-seed weight (HSW). The results are presented under the following headings:

4.1 Inheritance of stem pigmentation and flower colour

4.3 Determination of genotypes for white flower colour

4.3 Associations among important traits

4.1 Inheritance of stem pigmentation and flower colour

4.1.1 Stem pigmentation

The inheritance of stem pigmentation (anthocyanin) was studied in the F_2 and F_3 generations of the cross ICC 5716 x ICC 17101. In the F_2 generation 106 low and 48 high pigmented plants were obtained. Based on one-gene segregation and with low pigmentation dominant to high pigmentation, this fits well to the expected ratio of 3:1 (Table 2).

The data for F_3 generation of the above cross, confirmed the results of F_2 generation indicating that the stem pigmentation is controlled by a single gene (Table 3).

4.1.2Flower colour

In this cross this cross the inheritance of flower colour was also studied. The observations obtained in F_2 generation were 121 pink: 33 white. Based on one gene segregation these fit well to the expected ratio of 3:1 (Table 2).

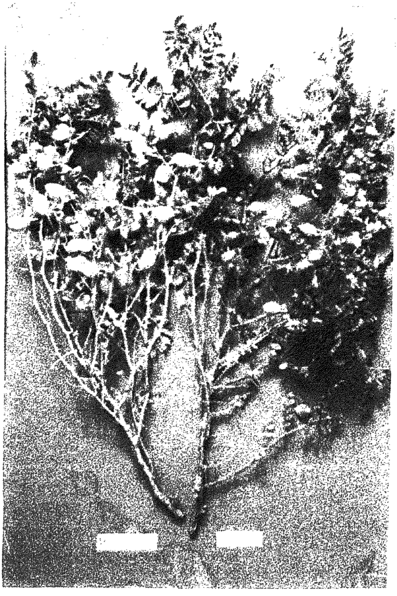
The F_3 generation of the above cross also confirmed the results of F_2 generation segregation, indicating that the pink flower colour is controlled by a single gene (Table 3).

Table 2: Segregation for stem pigmentation and flower colour in the F_2 generation of the cross ICC 5716 x ICC 17101

Cross	Character	Phenotype	Observed Number	Approp-riate Ratio	χ^2	P
ICC 5716 x ICC 17101 (F_2generation)	Stem pigmentation	Low	106	3	3.125^{ns}	0.10 - 0.05
		High	48	1		
	Flower colour	Pink	121	3	1.040^{ns}	0.50-0.30
		White	33	1		

Plate 1 Parents showing high pigmented stem ICC5716,low pigmented stem ICC 17101

Plate 2 Parents showing pink flowerICC5716 and white flower ICC17101



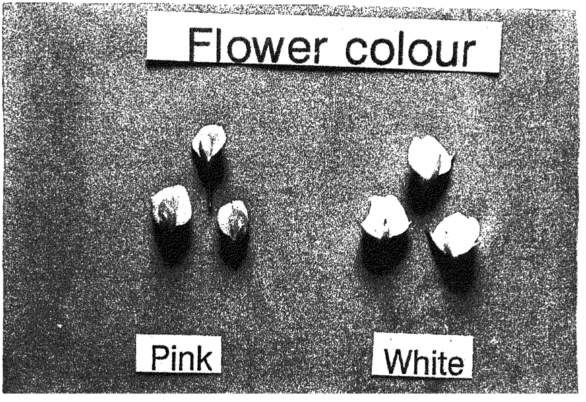

Flower colour
Pink
White

Table 3: Segregation for stem pigmentation and flower colour in the F_3 generation of the cross ICC 5716 x ICC 17101

Cross	Character	Pheno type	Observed Number	Appropriate Ratio	χ^2	P
ICC 5716 x ICC 17101 (F_3 generation)	Stem pigmentation	Low	665	7	0.034^{ns}	0.50-0.30
		High	295	3		
	Flower colour	Pink	683	7	0.040^{ns}	0.50-0.30
		White	277	3		

4.1.3 Joint segregation of stem pigmentation and flower colour

In the F_2 population the joint segregation of stem pigmentation and flower colour was studied together. Four classes of stem pigmentation and flower colour were obtained indicating that two genes governed these traits (Table 4). The four classes; low pigmentation with pink flower, low pigmentation with white flower, high pigmentation with pink flower and high pigmentation with white flower fit well to a 9: 3: 3:1 ratio (χ^2 value was 4.30^{ns} at 3 d.f). F_3 generation data confirmed the results of F_2 generation (Appendix no. 1). This indicated that the two genes segregated independent of each other.

Table 4: Joint segregation of stem pigmentation and flower colour in F_2 generation of the cross ICC 5716 x ICC 17101

Phenotype	Observed number	Appropriate ratio	χ^2	P
Low pigmented with pink flowers	84	9	4.300[ns]	0.30-
Low pigmented with white flowers	22	3		0.20
High pigmented with pink flowers	37	3		
High pigmented with white flowers	11	1		
Total	**154**	**16**		

4.2 Determination of different genotypes of white flower colour

The crosses between ICCV 2 (white) **x** T-1-A (blue) and RS 11(white) **x** T 39-1 (blue) produced pink flower colour in F_1 indicating interaction of bluc with white flower colour. In the F_2 generation of both crosses were resulted in three types of flower colours pink, blue and white indicating supplementary type of gene action and their expected genotypes were showed. (Table 5).

By crossing these white flowers { F_2 white flower of (ICCV 2 x T-1-A) **x** F_2 white flower of (RS 11 x T 39-1)} produced pink and blue flowers .The F_2 generation of these cross resulted in three types of flower colours pink, blue and white. The expected genotypes for these flower colours and the parents involved in the crosses were in given (Table 7). From the F2 generation of this cross the resulting genotypes for white flower colour were: *C-bbP- ccB-P- ccB-P- C-bbpp* and *ccbbpp*. Triple recessive genotype i.e., ***ccbbpp*** was determined for white flower colour from the F_2 generation of this cross. The possibility of getting triple recessive genotype for white flower color was given in Table 6.

Table 5 : Crossing and segregation of parents for determination of different genotypes for white flower colour

Cross	Generation	Phenotype	Genotype	Appropriate Ratio	Type of Interaction
ICCV 2 **x** T-1-A		White **x** Blue	*CCbbPP* **x** *CCBBpp*		
	F_1	Pink	*CCBbPp*		
	F_2	Pink Blue White	*CC B-P* *CCB-pp* *CCbbP-* *CCbbpp*	9 3 4	Supplementary gene
RS-11 **x** T 39-1		White **x** Blue	*ccBBPP* **x** *CCBBpp*		
	F_1	Pink	*CcBBPp*		
	F_2	Pink Blue White	*C-BBP-* *C-BBpp* *ccBBP-* *ccBBpp*	9 3 4	Supplementary gene

Table 6: Table showing possibility of crosses among white flowers from the crosses of ICCV 2x T-1-A and RS 11 x T 39-1

		RS 11 x T 39-1 F_2 white flower genotypes		
		ccBBPP 1	*ccBBPp* 2	*ccBBpp* 1
ICCV 2 x T-1-A F_2 white flower genotypes	*CCbbPP* 1	pink 1	**pink**:bluc 2:2	pink 1
	CCbbPp 2	**pink** 2	**pink: blue** 3:1	**pink: blue** 1:1
	CCbbpp 1	**pink** 1	**pink:blue** 1:1	**blue** 1

Note: Selfing the high lighted phenotypes can produce tripple recessive genotype for white flower colour

Table 7: Crossing pattern and segregation of white flower types from both crosses for getting triple recessive genotype for white flower colour

Cross	Generation	Phenotype	Expected Genotype	Appropriate Ratio	Type of interaction
(ICCV2 x T-1-F_2 white) **x**		White **x**	*CCbbPP* **x**		
(RS 11 x T 39-1 F_2		White	*ccBBPP*		
white)	F_1	Pink	*CcBbPP*		
				9:7	Complim-entary gene action
	F_2	Pink	*C-B-PP*		
		White	*C-bbPP*		
			ccB-PP		
			ccbbPP		
ICCV2 x T-1-F_2 white) **x**		White **x**	*CCbbPp* **x**		
(RS 11 x T 39-1 F_2		White	*ccBBPP*	3:1	
white	F_1				
		Pink	*CcBbPp*		
		blue	*CcBbpp*		
	F_2 Pink	Pink	*C-B-P-*	9:3:4 27:9:12	Supple-mentary gene action
		Blue	*C-B-pp*		
		White	*C-bbP-*		
			C-bbpp		
			ccB-P-		
			ccB-pp		
			ccbbP-		
			ccbbpp		
		Blue	*C-B-pp*		
	F_2 Blue	White	*C-bbpp*	9:7	Complim-entary gene action
			ccB-pp		
			ccbbpp		
ICCV2xT-1-A F white) **x**		White **x**	*ccBBpp* **x**		
(RS 11 x T 39-1 F_2		White	*CCbbpp*		
white	F_1	Blue	*CcBbpp*		
	F_2	Blue	*C-B-pp*	9:7	Complim-entary gene action
		White	*C-bbpp*		
			ccB-pp		
			ccbbpp		

4.3 Association among important traits in the cross

4.3.1 Associations among important traits in the cross ICC5716 x ICC17101

4.3.1.1 Days to 50 % flowering

Days to 50 % flowering was significant and positively correlated with days to first flowering (0.693**), days to first pod formation (0.600**), days to maturity (0.261**) and with 100 seed weight (0.198**) in F_2 generation.

Days to 50 % flowering was not having any association with recorded characters in F_3 generation

4.3.1.2 Days to first flowering

Days to first flowering was significant and positively correlated with days to first pod formation (0.921**), days to maturity (0.274**) and with 100 seed weight (0.172*) in F_2 generation.

Days to first flowering was significant and positively correlated with days to first pod formation (0.803**) and significantly negative correlation with initial plant stand (-0.308**) in F_3 generation.

4.3.1.3 Days to first pod

Days first pod formation was significant and positively correlated with days to maturity (0.230**), 100-seed weight (0.200*) and with days to 50 per cent flowering (0.600**) in F_2 generation.

Days first pod was significant and positively correlated with days first flowering (0.083**) and negatively correlated with initial plant stand (-0.399**) in F_3 generation.

Table 8 Phenotypic correlation coefficients for the F2 and F3 generations of ICC5716 x ICC17101

		D50%F	DFF	DFP	DM	HSW	HT	IPS	NPP	NSP	PB	SB	WD
DFF	F2	0.693**											
	F3	0.099											
DFP	F2	0.6**	0.92**										
	F3	0.5**	0.803**										
DM	F2	0.26**	0.274**	0.23*									
	F3	-0.005	0.084	0.095									
HSW	F2	0.98**	0.72*	0.2**	0.055								
	F3	-0.022	0.09	0.5**	-0.46								
HT	F2	0.06	-0.04	-0.085	0.208**	0.03							
	F3	-0.025	0.22**	-0.06	-0.005	0.45**							
IPS	F2	-0.2	-0.06	-0.023	0.64*	-0.44	-0.022						
	F3	0.032	0.308**	0.399**	-0.9	-0.049	0.074						
NPP	F2	-0.08	-0.098	-0.065	0.69*	0.005	0.458**	0.28**					
	F3	0.01	0.099	0.042	-0.02	-0.04	0.435**	-0.066					
NSP	F2	-0.06	-0.086	-0.075	-0.111	-0.025	0.455**	0.063	0.893**				
	F3	-0.07	-0.08	-0.098	0.05	-0.38	0.455**	-0.039	0.802**				
PB	F2	0.054	-0.022	0.08	-0.065	0.49**	0.200**	0.079	-0.072	-0.097			
	F3	-0.075	0.48**	0.027	-0.036	0.06	0.39**	0.101	0.275**	0.275**			
SB	F2	0.048	-0.05	-0.49	0.09	0.065	0.375**	-0.04	0.395**	0.45**	0.32**		
	F3	-0.095	0.049	-0.05	0.29**	-0.002	0.228**	-0.44	0.252**	0.262**	0.304**		
WD	F2	0.09	-0.027	-0.05	-0.002	-0.075	0.606**	0.043	0.539**	0.568**	0.46**	0.378**	
	F3	-0.025	0.33**	0.093	-0.04	0.029	0.483**	0.111	0.358**	0.382**	0.344**	0.035	
Yld_P	F2	-0.025	0.33**	0.093	-0.04	0.029	0.5**	0.07	0.864**	0.382**	0.344**	0.035	0.566**
	F3	0	0	-0.06	-0.054	0.077	0.547**	-0.07	0.83**	0.875**	0.32**	0.300**	0.470**

* Significant at 5% level

**Significant at 1%level

4.3.1.4 Days to maturity

Days to maturity was significant and positively correlated with days to 50 per cent flowering (0.261**), days to first flowering (0.274**) and days to first pod formation (0.230**) while negatively correlated significantly with plant height (-0.208**), initial plant stand (-0.164*) and with number of pods per plant (-0.169*) in F_2 generation.

Days to maturity was not having any correlations with the recorded characters in F_3 generation

4.3.1.5 100 seed weight

Hundred seed weight significant and positively correlated with days to 50 % flowering (0.198*) and with days to first flowering (0.172*) in F_2 generation.

Hundred seed weight was not having any association with the recorded characters in F_3 generation.

4.3.1.6 Plant height

Plant height was significant and positively correlated with number of pods per plant (0.458**), number of seeds per plant (0.455**), number of secondary branches (0.375**), plant width (0.606**) and with yield per plant (0.500**) in F_2 generation.

Plant height was significant and positively correlated with number of pods per plant (0.435**), number of seeds per plant (0.455**), number of primary branches per plant (0.319**), number of secondary branches (0.228**), plant width (0.483**) and with yield per plant (0.547**) in F_3 generation.

4.3.1.7 Initial plant stand

Initial plant stand was significant and negatively correlated with days to maturity (-0.164*) and with other characters no association is observed in F_2 generation.

Initial plant stand was negatively correlated significantly with days to first flowering (-0.308**) and with days to first pod formation (-0.399**) in F_3 generation.

4.3.1.8 Number of pods per plant

Number of pods per plant was significant and positively correlated with plant height (0.458**), number of seeds per plant (0.893**), number of secondary branches per plant (0.395**), width of the plant (0.539**), yield per plant (0.864**) and was negatively correlated significantly with days to maturity (-0.169*) in F_2 generation.

Number of pods per plant was significant and positively correlated with plant height (0.435**), width of the plant (0.358**), number of seeds per plant (0.802**), number of primary branches per plant (0.275**), number of secondary branches per plant (0.252**) and with yield per plant (0.813**) in F_3 generation.

4.3.1.9 Number of seeds per plant

Number of seed per plant was significant and positively correlated with plant height (0.455**), width of the plant (0.568**), number of secondary branches (0.451**) and with yield per plant (0.946**) in F_2 generation.

Number of seed per plant was significant and positively correlated with plant height (0.455**), width of the plant (0.382**), number of primary branches (0.275**), number of secondary branches (0.262**) and with yield per plant (0.875**) in F_3 generation.

4.3.1.10 Number of primary branches per plant

Number of primary branches per plant was not having any association with the recorded characters in F_2 generation.

Number of primary branches per plant was significant and positively correlated with height of the plant (0.319**), width of the plant ().344**), number of secondary branches per plant (0.304**) and with yield per plant (0.312**) in F_3 generation.

4.3.1.11 Number of secondary branches per plant

Number of secondary branches per plant was significant and positively correlated with plant height (0.375**), width of the plant (0.378**), number of pods per plant (0.395**) and with number of seeds per plant (0.451**) in F_2 generation.

Number of secondary branches per plant was significant and positively correlated with plant height (0.228**), number of primary branches per plant (0.304**), number of pods per plant (0.252**) and with number of seeds per plant (0.262**) in F_3 generation.

4.3.1.12 Width of the plant

Width of the plant was significant and positively correlated with plant height (0.606**), number of pods per plant (0.539**), number of seeds per plant (0.568**) and with number of secondary branches per plant (0.378**) in F_2 generation.

Width of the plant was positively correlated significantly with plant height (0.483**), number of pods per plant (0.358**), number of seeds per plant (0.382**) and with number of primary branches per plant (0.344**) in F_3 generation.

4.3.1.13 Yield per plant

Yield per plant was significant and positively correlated with plant height (0.500**), width of the plant (0.566**), number of pods per plant (0.864**), number of seeds per plant (0.946**), and with number of secondary branches per plant (0.447**) in F_2 generation.

Yield per plant was significant and positively correlated with plant height (0.547**), width of the plant (0.417**), number of pods per plant (0.813**), number of seeds per plant (0.875**), with number of primary branches per plant (0.312**) and with number of secondary branches per plant (0.312**) in F_3 generation.

4.3.2 Associations among different white flower colour genotypes

In the cross F_2 white flower ICCV 2 x T-1-A x F_2 white flower RS 11 x T 39-1 the relationships of quantitative characters were studied among white flower genotypes to find out the association among traits. Correlation coefficients were calculated. The magnitude and direction of association among morphological traits in this cross were presented below.

4.3.2.1 100 Seed weight:

Hundred Seed Weight was correlated negatively significant with days to maturity (-O.174*) and with number of pods per plant (-0.286**) and with number of seeds per plant (-0.182*).

4.3.2.2 Days to 50% flowering

Days to 50% flowering was a correlated positively highly significant with days to first flower (0.791**) and with days to first pod (0.779**) and with days to maturity (0.409*) and with plant height, (0.46**) and with number of secondary branches (0.293**) and with plant width (0.392**).

Table 4 b Correlation coefficients for the F2 generation of ICC5716 x ICC 17101

	D50%F	DFF	DFP	DM	HSW	HT	IPS	NPP	NSP	PB	SB	WD	Yld_P
D50%F	1												
DFF	0.693**	1											
DFP	0.6**	0.921**	1										
DM	0.261**	0.274**	0.23*	1									
HSW	0.198*	0.172*	0.2	0.055	1								
HT	0.016	-0.041	-0.085	0.208**	0.03	1							
IPS	-0.12	-0.061	-0.023	0.164*	-0.144	-0.022	1						
NPP	-0.108	-0.098	-0.065	0.169*	0.005	0.458**	0.128	1					
NSP	-0.106	-0.086	-0.075	-0.111	-0.025	0.455**	0.063	0.893**	1				
PB	0.054	-0.022	0.018	-0.065	0.149	0.121	0.079	-0.072	-0.097	1			
SB	0.048	-0.105	-0.149	0.091	0.065	0.375**	-0.104	0.395**	0.451**	0.132	1		
WD	0.019	-0.027	-0.05	-0.002	-0.075	0.606**	0.043	0.539**	0.568**	0.146	0.378**	1	
Yld_P	-0.108	-0.087	-0.06	-0.116	0.109	0.5	0.07	0.864**	0.946**	-0.056	0.447**	0.566	1

* Significant at 5% level

**Significant at 1%level

4.3.2.3 Days to first flowering

Day to first flower was positively correlated highly significant with days to first pod (0.941**) and with days to maturity (0.266**) and with plant height (0.420**) and with number of secondary branches (0.338**) and with width of the plant (0.355**).

4.3.2.4 Days to first pod

Days to first pod was positively correlated significant with days to maturity (0.297**), and with plant height (0.401**) and with number of secondary branches per plants (0.310**) and with width of the plant (0.359**).

4.3.2.5 Days to maturity

Days to maturity was positively correlated and significant with plant height (0.312**) and with number of secondary branches (0.179*) and with width of the plant (0.334**).

4.3.2.6 Plant height

Plant height was correlated positively highly significant with number of pods per plant (0.272**) and with days to maturity (0.312**) and with width of the plant (0.602**) and also highly significantly correlated with days to 50% flowering (0.446**) and with days to first flowering (0.420**) and with days to first pod formation (0.401**) and with days to maturity (0.312**).

4.3.2.7 Number of pods per plant

Number of pods per plant was positively correlated significantly with plant height (0.272**) and with number of secondary branches per plant (0.516**) and with number of seeds per plant (0.418**) and with width of the plant (0.428**) and with yield per plant

(0.205**) but number of pods per plant was negatively correlated with 100 seed weight (-0.286**).

4.3.2.8 Plant width

Plant width correlated highly significant with days to 50% flowering (0.392**) and with days to first flower (0.355**) and with days to first pod (0.359**) and with days to maturity (0.334**) and with plant height (0.602**) and with number of pods per plant (0.428**).

4.3.2.9 Yield per plant

Yield per plant is not having any associations with other recorded characters except with number of pods per plant (0.255**)

4.3.2.10 Number of primary branches per plant

Number of primary branches per plant is not having any associations with other the recorded characters which were studied.

Discussion

CHAPTER V
DISCUSSION

This study was conducted to investigate inheritance of stem pigmentation and flower colour, to determine different genotypes for white flower colour and to compute associations among important traits in two crosses of chickpea. The results are discussed under the following headings:

5.1 Inheritance of stem pigmentation and flower colour.

5.2 Determination of different genotypes for white flower colour.

5.3 Associations among important traits.

5.1 Inheritance of stem pigmentation and flower colour.

Flower colour has profound effect on other morphological and physiological patterns. The inheritance of stem pigmentation and flower colour was studied in chickpea cross ICC 5716 x ICC 17101. ICC 5716 has light purple stem and pink flowers. ICC 17101 has high purple stem and white flowers.

The stem pigmentation was controlled by a single gene pair in the present study. Similar results were obtained by Bhapkar and Patil (1962), Aher and Patil (1984), Singh and Singh (1995), Tefera (1998) and Sabaghpour (2000). In the present study low stem pigmentation was found to be dominant over high stem pigmentation. However, Essomba *et al.* (1987), Metz *et al.* (1992), Singh *et al.* (1993), Ghatge (1994a), Mathur (1998), Tefera (1998), Venugopal and Goud (1998) and Sabaghpour (2000) reported that high pigmentation was dominant to low/no pigmentation. Ghatge and Kolhe (1985), Kabir and Sen (1991), Karkannavar *et al.* (1991), Ghatge (1993) (1994a) and Mathur (1998) reported digenic control for the stem pigmentation. In addition to this complimentary type of gene action was reported by Ghatge and Kolhe (1985), Karkannavar *et al.* (1991) Mathur (1998) and Venugopal and Goud (1998) for pigmented and no/low pigmented characters.

In chickpea purple foliage colour could be used as a marker in identification of true hybrids (Sandhu *et al.*,1993). Mathur (1989) reported that this purple pigmentation depends on sunlight. Sandhu *et al.* (1993) indicated that pigmentation remained stable from seedling stage to plant maturity in ICC 6071.

Flower colour is also an important morphological marker in chickpea. In this study pink flower colour is dominant over white flower color indicating that a single gene governs this character. These results support those of Pimplikar (1943), Khan *et al.* (1950), Bhapkar and Patil (1962 and 1963), Gil and Cubero (1993), Tefera (1998) and Sabaghpour (2000), suggesting that the white flower colour is recessive to the pink flower color. But Khan and Akthar (1934), Kadam *et al* . (1941) Pawar and Patil (1979) Ghatge (1994a) and Kumar (1997) reported that two genes controlled this character. Ayyar and Balasubramanian (1936), D'cruz and Tendulkar (1970), Phadnis (1976), Vijayalakshmi (1998) and Kumar *et al.* (2000) suggested trigenic inheritance for this character. According to them all the three genes *i.e* *C*, *B* and *P* should be present in the dominant condition to produce pink flower colour. When *C* and *B* are in dominant condition blue colour is produced and when either *B* or *C* is in homozygous recessive condition white flower colour is produced.

In the joint segregation for stem pigmentation and flower colour, these two characters segregated in a 9:3:3:1 ratio indicating that both the characters were governed by two different genes that showed independent assortment. These results vary from those proposed by Aher and Patil (1984), Ghatge (1994b), Joshi *et al.* (1994), Tefera (1998), and Sabaghpour (2000). They found that the gene that governs the flower colour has pleiotropic effect on stem pigmentation. From the above discussion stem pigmentation and flower colour can show monogenic, digenic and trigenic inheritance depending on the parental genotypes.

5.2 Determination of different genotypes of white flower colour:

In chickpea, three distinct flower colours are identified namely pink, blue and white. The flower colour is an important trait since it is a reliable morphological marker for comparing chickpea accessions. Most of the desi varieties of chickpea are of pink flowered type and kabuli types always have white flowers. White flower accessions account for about one third of the world germplasm and those with blue flowers are rare (Pundir et al., 1988).

The cross between two white flowered parents ICCV 2 and RS 11 produced pink flower. These two parents when crossed to blue flowered parents T-1-A and T 39-1 also produced pink flowers. This indicated an interaction between the genes for white and blue flower colours resulting in the formation of pink flowers in the F_1s. This also suggested the involvement of more than one gene in governing the flower colour. These results differ from those of Pimplikar (1943), Khan *et al.*.(1950), Bhapkar and Patil

(1963), Patil (1964), Athwal and Brar (1967), Patil (1967), Khosh-Khui and Niknejad (1971), More and D'cruz (1976), Nayeem *et al.* (1977), Reddy and Nayeem (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.

F_2 of these crosses segregated in the ratio of 9 pink: 3 blue: and 4 white flower colour individuals, indicating the 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), Patil and Deshmukh (1975), Reddy and Chopde (1977), Pawar and Patil (1979), Rao *et al.* (1980), Davis (1991) and Kumar (1997). According to the digenic model assuming gene designation are proposed by Khan and Akhtar (1934), a dominant factor *B* produced blue colour. A factor *P* produced 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, LRCO*, 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 flower colours in the F_2 generation of both the crosses was indicative of similar genetic constitution of the two white flowered parents ICCV 2 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 for their white colours. Hence the digenic model of inheritance was not found to be appropriate (Kumar *et al.* 2000).

The possible white flower color genotypes of the above crosses will be *ccBBPP*, *ccBBPp*, *ccBBpp* from ICCV2 **x** T-1-A cross , *CCbbPP*, *CCbbPp* and *CCbbPP* from RS 11 **x** T 39-1cross.

From the intercrossing of the above mentioned different genotypes for white flower colour from the two crosses, the F_1 was pink. F_2 segregated pink and white. In this case the type of interaction observed is complimentary (9:7). So the expected genotypes of the parents involved in this cross were *CCbbPP* **x** *ccBBPP*. The genotype for pink flower is *C-B-P-* and the white flower genotypes are *C-bbP-*, *ccB-P-* and *ccbbP-*.

In other cross between white flowered genotypes, pink and blue flowered plants were produced. So the expected genotypes of the parents involved in this cross were *ccBBpp* **x** *CCbbPp* pink and blue flowered plants were with *CcBbPp* and *CcBbpp* genotypes. Selfing these plants produced some tripple recessive genotypes for white flower colour.

From the other cross between the white flowered genotypes in F_1 pink and blue flowers were resulted. So the expected genotypes of the parents involved in this cross were *CCbbPP* **x** *CcBbpp*, the F_1 pink genotype is *C-B-P-* and blue genotype is *C-B-pp*.

F_2 segregation of pink colour gave all three flower colours pink *C-B-P-*, blue with *C-B-pp* and white with *CCbbpp, CcbbPP, CcbbPp, CCbbpp, ccBBPP, ccBBPp, ccBBpP, ccBbPP, ccBbPp, ccBbpp, ccbbPP, ccbbPp* and *ccbbpp*. Here also we got tripple recessive genotypes and blue flowers segregated into blue *C-B-pp* and white with *C-bbpp, ccB-pp, ccB-Pp* and *ccbbpp*.

Thus from this study flower colour was observed to be governed by three genes and white flowered genotypes can have different constitution as proposed by Ayyar and Balasubramanian (1936) Davis (1991), Vijayalakshmi (1998), Tefera (1998), Kumar *et al.* (2000). In this study various genetic constitutions for white flower colour including one tripple recessive homozygous genotype were determined.

Considering the occurance 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 evolution of this character.

5.3 Association of traits in the cross ICC 5716 x ICC 17101

An understanding of the nature of association of yield and yield contributing characters are of great significance in proper planning of selection programmes and genetic improvement of these characteristics. The association are from this study are discussed here under.

In the cross ICC 5716 x ICC 1 7101 in F_2 and F_3 generations seed yield per plant is positively correlated with plant height (0.50**) (0.547**) respectively. But this is varies with Reddy and Rao (1988), Jahhar and Manne (1991), Ali (1990), Yadav (1990), Bhambota *et al* (1994), Akdag and Sehirali (1992), Sathe *et al* (1993), Arora and Kumar (1994), Lal *et al* (1993), Sandhu and Mangath (1995) who reported negative association with yield and no association was reported by Reddy and Rao (1988), Jahhar and Manne (1991) and Vijayalakshimi (1998).

Yield is positively correlated with number of pods per plant in F_2 and F_3generations (0.864**), (0.813**) respectively. (Salimath and Bahl, 1986; Mishra *et al.* 1988; Reddy and Rao, 1988; Yadav, 1990; Abdali, 1992; Chavan *et al.*, 1994; Ozdemer, 1996; Manjare *et al.*, 1997; Vijayalakshmi, 1998).

Yield per plant is highly positively correlated with number of seeds per plant in both F_2 and F_3 generation. (0.946**) and (0.875**) respectively, supporting Reddy and Rao (1988), Sandhu and Mandal (1989), Yadav (1990), Akdag and Sehirali (1992), Sathe *et al.* (1993), Chand and Singh (1997), Vijayalakshmi (1998) and Sabaghpour (2000).

Yield per plant is positively correlated with number of secondary branches in F_2 (Sharma and Maloo (1988); Uddin *et al* (1990); Abdali (1992); Rao *et al* (1994); Khorgade *et al.* (1995) and Manjare *et al* (1997), Vijayalakshmi (1998), Sabaghpour (2000) in F_3 no association was observed for secondary branches.

Yield per plant is positively correlated with number of primary branches per plant in F_3. (Salimath and Bahl, 1986, Mishra *et al.* 1988; Chavan *et al.*,1994; Manjare *et al.*, 1997; and Vijayalakshimi, 1998). In F_2 generation number of primary branches per plant is having no association with yield per plant. Yield per plant is positively correlated with width of the plant in both F_2 and F_3 generations.

Yield per plant shows non significant correlation in both F_2 and F_3 generations with, days to 50% flowering. But Ali (1990), Sarvaliya and Goyal (1994), Sandhu and Mangath (1995), Qayyum *et al.* (1997) and Raghu (2001) reported association with yield per plant.

In both F_2 and F_3generations yield per plant is showing non significant correlation with days to maturity (Bhambotha *et al*,1994; Raghu, 2001), but negative association was observed by Qayyum *et al*, (1997). Yield per plant is showing no correlation with days to 50% flowering in both F_2 and F_3 generations. But Rahman and Parth (1988) and Raghu (2001) reported negative association with yield per plant.

Yield per plant showing no association in both F_2 and F_3 generations with days to first pod formation. This is differing from Qayyum *et al.* (1997) and Raghu (2001).Yield per plant showed non significant association with 100 seed weight and initial plant stand.

5.3.1 Association of traits among different genotypes of white flower colour

Phenotypic correlation studies were carried out to find out the associations among important traits from different white flower colour genotypes..

Yield per plant among white flower genotypes showed a non significant association with all the traits under study (Bhambotha *et al*, 1994 and Raghu, 2001) except with number of pods per plant (Manjare *et al.* 1997; Vijayalakshmi, 1998; Or *et al.*, 1999; Sabaghpour, 2000). Number of pods per plant is correlating with number of secondary branches per plant (Bejiga *et al.*, 1991 ; Chhina *et al.*, 1991; Abdali,1992; Vijayalakshmi, 1998). Plant height showed positive association with number of secondary branches per plant (Choudhary and Mian, 1988; Vijayalakshmi, 1998) and with number of pods per plant it varies from Vijayalakshmi (1998) who suggested negative association. Number of pods per plant is showing negative association with 100 seed weight (Lal *et al.*, 1993; and Vijayalakshmi,1998) while number of seeds per plant also showing negative association with 100-seed weight (Sandhu and Mandal,1989; Pundir *et al.*, 1991; Dasgupta *et al.*,1992; Sathe *et al* 1993). Days to 50% flowering is more positively associated with days to maturity (Arora and Jeena, 1999; and Raghu, 2001), days to first flowering is more positively associated with days to maturity (Sharma and Maloo, 1988; Raghu, 2001).

The study is useful as it showed that stem pigmentation and flower colour are not pleiotropic traits as has always been reported in the literature. This indicates that different mechanisms are operating for these characters. Further studies are needed to determine the genes for these traits in chickpea.

Development of tripple recessive genotype for white flower colour will simplify allelic tests for flower colour in future chickpea studies. These genotypes will be registered as genetic stocks.

Summary

CHAPTER VI

SUMMARY

The inheritance of stem pigmentation and flower colour and the association among important traits in chickpea (*Cicer arietinum* L.) were studied at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru, near Hyderabad, A.P. during the 2000-01 post- rainy season. The following two experiments were conducted:

Experiment I

In this experiment the inheritance of stem pigmentation and flower colour was investigated. Two accessions ICC 5716 and ICC 17101 were used as parents. ICC 5716 has stem with low purple pigmentation with pink flowers and ICC 17101 has stem with high purple pigmentation with white flowers. Data was recorded on stem pigmentation and flower colour. The following results were obtained:

Monogenic inheritance was confirmed for the two morphological characters low *vs* high pigmentation of stem and pink and white flower colour. Joint segregation for these two characters fit well to the digenic ratio of 9:3:3:1 for the data for F_2 generation, indicating independent assortment of the two genes. The traits showed no pleiotropic effect for stem pigmentation and flower colour. Low pigmented stem is dominant to the highly pigmented stem and pink flower is dominant to the white flower colour. The F_2 generation results were confirmed by those for the F_3 generation.

Correlations estimated among quantitative characters and yield in comparison of F_2 generation with F_3 generation, in both F_2 and F_3 generations yield per plant was

correlated positively with plant height and with number of seeds per plant, number of secondary branches per plant and with width of the plants. In F_2 number of primary branches per plant, and in F_3 days to maturity, 100 seed weight are not having associations with any other characters studied. In both F_2 and F_3 generations, number of pods per plant is positively correlated with plant height, plant width, number of seeds per plant, number of secondary branches per plant and with yield per plant.

Number of seeds per plant in both F_2 and F_3 generations, is positively correlated with plant height, number of secondary branches, plant width and with yield per plant. 100-seed weight in F_2 generation positively correlated with days to 50% flowering and with days to first flowering but in the F_3 generation no correlation is observed.

Experiment II

This was conducted to determine different genotypes for white flower colour. For this, four parents were used. ICCV 2, RS 11, T 39-1, and T-1-A. ICCV 2 and RS-11 are white flowered and the other two are blue flowered accessions. Crossing of ICCV 2 x T-1-A, and RS 11 x T 39-1 produced pink flowers in the F_1 generation. F_2 generation of these crosses segregated into three types of flowers pink, blue and white in 9:3:4 ratio indicating involvement of three genes and supplementary type of gene action. These are probably *C*, *B* and *P* loci as earlier reported in the literature. Therefore, the genetic constitution for the four parents and their respective F_1 and F_2 generations are as follows: ICCV 2 (white) *CCbbPP*, T-1-A (blue) *CCBBpp*, F_1 *CCBbPP* (pink) F_2 *C-B-P-* (pink), *C-B-pp* (blue) and white *C-bbP-* and *C-b-pp*. RS 11 (white) *ccBBPP*, T 39-1 (blue)

CCBBpp, F_1 *CcBBPp*, F_2 *C-BBP-* (pink), *C-BBpp* (blue) and for white *ccBBP-* and *ccBBpp*.

The white flowers from the two crosses were intercrossed which resulted in pink and blue flowers. The F_1 generation of these crosses some pink flowered plants segregated into all three types; pink, blue and white showing (9:3:4) supplementary type gene action, some blue flowered plants segregated into blue and white flowers and indicating (9:7) complimentary type of action. From both pink and blue flowered plants white flowered progenies resulted that may have the tripple recessive genotypes. Some white flower plant genetic constitution may be heterozygous condition. However, for the first time a chickpea with a tripple recessive ***ccbbpp*** genotype for white flower colour has been determined.

Yield per plant among different white flower types showed no association with any traits under study except with number of pods per plant. 100 seed weight was negatively correlated with days to maturity and with number of pods per plant with number of seeds per plant. Days to 50% flowering was positively highly correlated significantly with days to first flowering, days to first pod, days to maturity, plant height and plant width. Number of pods per plant was positively correlated significantly with plant height, number of secondary branches, and with number of seeds per plant, and with plant width and with yield per plant but positively correlated with 100 seed weight.

The study is useful as it showed that stem pigmentation and flower colour are not pleiotropic traits as has always been reported in the literature. Development of tripple recessive genotype for white flower colour will simplify allelic tests for flower colour in future chickpea studies.

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* : Original not seen

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Appendices

Appendix 1

Segregation pattern of F3 generation of the cross ICC 5716 x ICC 17101

Replication 1

Ent.no	F2	Hp P	Hp W	Lp P	Lp W
1	Hp P	Hp P	•	•	•
2	Lp P	Hp P	•	Lp P	Lp W
3	Lp P	•	•	Lp P	Lp W
4	Lp P	Hp P	•	Lp P	•
5	Lp P	Hp P	Hp W	Lp P	Lp W
6	Hp P	Hp P	Hp W	•	•
7	Hp P	Hp P	Hp W		•
8	Lp P	Hp P	•	Lp P	•
9	Lp P	•	•	Lp P	Lp W
10	Lp P	Hp P	•	Lp P	•
11	Hp P	Hp P	Hp W	•	•
12	Lp W	•	Hp W	•	Lp W
13	Lp W	•	Hp W	•	Lp W
14	Lp W	•	•	•	Lp W
15	Lp W	•	•	•	Lp W
16	Lp P	•	•	Lp P	•
17	Hp W	•	Hp W	•	•
18	Lp P	•	•	Lp P	Lp W
19	Hp W	•	Hp W	•	•
20	Hp P	Hp P	•	•	•
21	Lp P	Hp P	Hp W	Lp P	Lp W
22	Hp P	Hp P	•	•	•
23	Lp P	Hp P	Hp W	Lp P	Lp W
24	Lp W	•	Hp W	•	Lp W
25	Lp W	•	•	•	Lp W
26	Lp W	•	Hp W	•	Lp W
27	Lp P	•	•	Lp P	Lp W
28	Lp W	•	Hp W	•	Lp W
29	Hp P	Hp P	Hp W	•	•
30	Lp P	Hp P	Hp W	Lp P	•
31	Hp P	Hp P	Hp W	•	•
32	Hp P	Hp P	Hp W	•	•
33	Lp P	Hp P	Hp W	Lp P	Lp W
34	Hp W	•	Hp W	•	•
35	Lp P	Hp P	Hp W	Lp P	Lp W
36	Lp P	•	•	Lp P	Lp W
37	Hp P	Hp P	Hp W	•	•
38	Lp P	•	Hp W	•	Lp W
39	Lp W	Hp P	•	Lp P	Lp W
40	Lp P	•	Hp W	•	Lp W
41	Lp P	•	•	Lp P	Lp W
42	Hp W	•	Hp W	•	•
43	Hp P	Hp P	Hp W	•	•
44	Lp P	Hp P	Hp W	•	•
45	Lp P	Hp P	Hp W	Lp P	Lp W
46	Lp P	•	•	Lp P	Lp W
47	Hp P	Hp P	Hp W	•	•
48	Hp W	•	Hp W	•	•
49	Lp P	Hp P	Hp W	Lp P	Lp W
50	Lp P	Hp P	•	Lp P	Lp W
51	Hp P	Hp P	Hp W	•	•
52	Hp P	Hp P	•	•	•
53	Lp P	•	•	Lp P	Lp W
54	Lp P	Hp P	•	Lp P	•
55	Lp P	•	•	Lp P	•
56	Lp P	Hp P	•	Lp P	•

Replication 2

Ent.n	F2	Hp P	Hp W	Lp P	Lp W
1	Hp P	Hp P	•	•	•
2	Lp P	Hp P	Hp W	Lp P	Lp W
3	Lp P	•	•	Lp P	Lp W
4	Lp P	Hp P	•	Lp P	•
5	Lp P	Hp P	Hp W	Lp P	Lp W
6	Hp P	Hp P	Hp W	•	•
7	Hp P	Hp P	Hp W	•	•
8	Lp P	Lp P	•	Lp P	•
9	Lp P	•	•	Lp P	Lp W
10	Lp P	Lp P	•	Lp P	•
11	Hp P	Hp P	Hp W	•	•
12	Lp W	•	Hp W	•	Lp W
13	Lp W	•	Hp W	•	Lp W
14	Lp W	•	•	•	Lp W
15	Lp W	•	•	•	Lp W
16	Lp P	•	•	Lp P	•
17	Hp W	•	Hp W	•	•
18	Lp P	•	•	Lp P	Lp W
19	Hp W	•	Hp W	•	•
20	Hp P	Hp P	•	•	•
21	Lp P	Hp P	Hp W	•	Lp W
22	Hp P	Hp P	•	•	•
23	Lp P	Hp P	Hp W	Lp P	Lp W
24	Lp W	•	Hp W	•	Lp W
25	Lp W	•	•	•	Lp W
26	Lp W	•	Hp W	•	Lp W
27	Lp P	•	•	Lp P	Lp W
28	Lp W	•	Hp W	•	Lp W
29	Hp P	Hp P	Hp W	•	•
30	Lp P	Hp P	Hp W	Lp P	Lp W
31	Hp P	Hp P	Hp W	•	•
32	Hp P	Hp P	Hp W	•	•
33	Lp P	Hp P	Hp W	Lp P	Lp W
34	Hp W	•	Hp W	•	•
35	Lp P	Hp P	Hp W	Lp P	Lp W
36	Lp P	•	•	Lp P	Lp W
37	Hp P	Hp P	Hp W	•	•
38	Lp W	•	Hp W	•	Lp W
39	Lp P	Hp P	Hp W	Lp P	Lp W
40	Lp W	Hp P	Hp W	•	Lp W
41	Lp P	•	•	Lp P	Lp W
42	Hp W	•	Hp W	•	•
43	Hp P	Hp P	Hp W	•	•
44	Hp P	Hp P	Hp W	•	•
45	Lp P	Hp P	Hp W	Lp P	Lp W
46	Lp P	•	•	Lp P	Lp W
47	Hp P	Hp P	Hp W	•	•
48	Hp W	•	Hp W	•	•
49	Lp P	Hp P	•	Lp P	Lp W
50	Lp P	Hp P	Hp W	Lp P	Lp W
51	Hp P	Hp P	Hp W	•	•
52	Hp P	Hp P	•	•	•
53	Lp P	•	•	Lp P	Lp W
54	Lp P	Hp P	•	Lp P	•
55	Lp P	•	•	Lp P	Lp W
56	Lp W	Hp P	•	Lp P	•

57 Lp	P	Hp P	•	Lp P	•	57 Lp	P	Hp P	•	Lp P	•
58 Lp	P	Hp P	Hp W	Lp P	Lp W	58 Lp	P	Hp P	Hp W	Lp P	Lp W
59 Hp	P	Hp P	•	•	•	59 Hp	P	Hp P	•	•	•
60 Lp	P	•	•	Lp P	Lp W	60 Lp	P	•	•	Lp P	Lp W
61 Lp	P	•	•	Lp P	Lp W	61 Lp	P	•	•	Lp P	Lp W
62 Lp	P	Hp P	Hp W	Lp P	Lp W	62 Lp	P	Hp P	Hp W	Lp P	Lp W
63 Lp	P	Hp P	Hp W	Lp P	Lp W	63 Lp	P	Hp P	Hp W	Lp P	Lp W
64 Lp	P	Hp P	Hp W	Lp P	Lp W	64 Lp	P	Hp P	Hp W	Lp P	Lp W
65 Hp	P	Hp P	•	•	•	65 Hp	P	Hp P	•	•	•
66 Lp	W	•	•	•	Lp W	66 Lp	W	•	•	•	Lp W
67 Lp	P	Hp P	Hp W	Lp P	Lp W	67 Lp	P	Hp P	Hp W	Lp P	Lp W
68 Hp	P	Hp P	Hp W	•	•	68 Hp	P	Hp P	Hp W	•	•
69 Lp	W	•	Hp W	•	Lp W	69 Lp	P	•	Hp W	•	Lp W
70 Lp	P	Hp P	Hp W	Lp P	Lp W	70 Lp	P	Hp P	Hp W	Lp P	Lp W
71 Lp	P	Hp P	•	Lp P	•	71 Lp	P	Hp P	•	Lp P	•
72 Lp	P	Hp P	Hp W	Lp P	Lp W	72 Lp	P	Hp P	•	Lp P	Lp W
73 Hp	P	Hp P	Hp W	•	•	73 Hp	P	Hp P	Hp W	•	•
74 Lp	P	Hp P	•	Lp P	•	74 Lp	P	Hp P	•	Lp P	•
75 Hp	P	Hp P	•	•	•	75 Hp	P	Hp P	•	•	•
76 Lp	P	•	•	Lp P	Lp W	76 Lp	P	•	•	Lp P	Lp W
77 Lp	W	•	•	•	Lp W	77 Lp	W	•	•	•	Lp W
78 Lp	P	•	•	Lp P	Lp W	78 Lp	P	•	•	Lp P	Lp W
79 Lp	P	Hp P	Hp W	Lp P	Lp W	79 Lp	P	Hp P	•	Lp P	Lp W
80 Hp	P	Hp P	•	•	•	80 Hp	P	Hp P	•	•	•
81 Lp	P	Hp P	Hp W	Lp P	•	81 Lp	P	Hp P	Hp W	Lp P	Lp W
82 Lp	P	Hp P	•	Lp P	•	82 Lp	P	Hp P	•	Lp P	•
83 Lp	P	•	Hp W	Lp P	Lp W	83 Lp	P	Hp P	•	Lp P	Lp W
84 Hp	P	Hp P	Hp W	•	•	84 Hp	P	Hp P	Hp W	•	•
85 Hp	W	•	Hp W	•	•	85 Hp	W	•	Hp W	•	•
86 Lp	P	Hp P	Hp W	Lp P	•	86 Lp	P	Hp P	Hp W	Lp P	Lp W
87 Hp	P	Hp P	Hp W	•	•	87 Hp	P	Hp P	Hp W	•	•
88 Lp	P	•	•	Lp P	•	88 Lp	P	•	•	Lp P	•
89 Lp	W	•	Hp W	•	Lp W	89 Lp	W	•	Hp W	•	Lp W
90 Lp	P	•	•	Lp P	Lp W	90 Lp	P	•	•	Lp P	Lp W
91 Hp	P	Hp P	Hp W	•	•	91 Hp	P	Hp P	Hp W	•	•
92 Lp	P	Hp P	•	Lp P	•	92 Lp	P	Hp P	•	Lp P	•
93 Hp	W	•	Hp W	•	•	93 Hp	W	•	Hp W	•	•
94 Lp	P	•	•	Lp P	Lp W	94 Lp	P	•	•	Lp P	Lp W
95 Lp	P	Hp P	Hp W	Lp P	Lp W	95 Lp	P	Hp P	Hp W	Lp P	Lp W
96 Hp	P	Hp P	•	•	•	96 Hp	P	Hp P	•	•	•
97 Lp	P	Hp P	•	Lp P	Lp W	97 Lp	P	Hp P	Hp W	Lp P	Lp W
98 Lp	P	Hp P	Hp W	Lp P	Lp W	98 Lp	P	Hp P	Hp W	Lp P	Lp W
99 Lp	P	Hp P	Hp W	•	•	99 Hp	P	Hp P	Hp W	•	•
100 Hp	P	Hp P	Hp W	•	•	100 Hp	P	Hp P	Hp W	•	•
101 Lp	P	Hp P	Hp W	Lp P	Lp W	101 Lp	P	Hp P	Hp W	•	Lp W
102 Lp	P	•	•	Lp P	Lp W	102 Lp	P	•	•	Lp P	Lp W
103 Lp	P	•	•	Lp P	•	103 Lp	P	•	•	Lp P	•
104 Lp	P	Hp P	•	Lp P	Lp W	104 Lp	P	Hp P	Hp W	Lp P	Lp W
105 Hp	P	Hp P	Hp W	•	•	105 Hp	P	Hp P	Hp W	•	•
106 Lp	W	•	Hp W	•	Lp W	106 Lp	W	•	Hp W	•	Lp W
107 Hp	P	Hp P	•	•	•	107 Hp	P	Hp P	•	•	•
108 Lp	P	Hp P	•	Lp P	•	108 Lp	P	Hp P	•	Lp P	•
109 Lp	W	•	Hp W	•	Lp W	109 Lp	W	•	Hp W	•	Lp W
110 Hp	P	Hp P	•	•	•	110 Hp	P	Hp P	•	•	•
111 Lp	W	•	Hp W	•	Lp W	111 Lp	W	•	Hp W	•	Lp W
112 Lp	P	Hp P	Hp W	Lp P	Lp W	112 Lp	P	•	Hp W	Lp P	Lp W
113 Lp	P	Hp P	•	Lp P	•	113 Lp	P	Hp P	•	Lp P	•
114 Lp	P	•	•	Lp P	Lp W	114 Lp	P	•	•	Lp P	Lp W
115 Lp	P	Hp P	Hp W	Lp P	Lp W	115 Lp	P	Hp P	Hp W	Lp P	Lp W
116 Lp	P	Hp P	Hp W	Lp P	Lp W	116 Lp	P	Hp P	Hp W	Lp P	Lp W

117	Lp	P	Hp P	*	Lp P	*	117	Lp	P	Hp P	*	Lp P	*
118	Hp	P	Hp P	*	*	*	118	Hp	P	Hp P	*	*	*
119	Lp	P	Hp P	*	Lp P	*	119	Lp	P	*	*	Lp P	Lp W
120	Lp	W	*	*	*	Lp W	120	Lp	W	*	*	*	Lp W
121	Hp	P	Hp P	Hp W	*	*	121	Hp	P	Hp P	Hp W	*	*
122	Lp	P	*	*	Lp P	Lp W	122	Lp	P	*	*	Lp P	Lp W
123	Lp	W	*	*	*	Lp W	123	Lp	W	*	*	*	Lp W
124	Lp	P	*	*	Lp P	Lp W	124	Lp	P	Hp P	*	Lp P	*
125	Lp	P	Hp P	*	Lp P	Lp W	125	Lp	P	Hp P	Hp W	Lp P	Lp W
126	Lp	P	*	*	Lp P	*	126	Lp	P	*	*	Lp P	*
127	Lp	P	Hp P	Hp W	Lp P	Lp W	127	Lp	P	Hp P	Hp W	Lp P	Lp W
128	Lp	P	Hp P	*	Lp P	Lp W	128	Lp	P	Hp P	Hp W	Lp P	Lp W
129	Hp	W	*	Hp W	*	*	129	Hp	W	*	Hp W	*	*
130	Lp	P	*	*	Lp P	Lp W	130	Lp	P	*	*	Lp P	Lp W
131	Lp	P	Hp P	Hp W	Lp P	Lp W	131	Lp	P	Hp P	Hp W	Lp P	Lp W
132	Lp	P	Hp P	*	Lp P	*	132	Lp	P	Hp P	*	Lp P	*
133	Hp	P	Hp P	Hp W	*	*	133	Hp	P	Hp P	Hp W	*	*
134	Lp	W	*	Hp W	*	Lp W	134	Lp	W	*	Hp W	*	Lp W
135	Lp	P	Hp P	*	Lp P	*	135	Lp	P	Hp P	*	Lp P	*
136	Hp	P	Hp P	Hp W	*	*	136	Hp	P	Hp P	Hp W	*	*
137	Lp	P	Hp P	Hp W	*	Lp W	137	Lp	P	Hp P	Hp W	Lp P	*
138	Lp	P	Hp P	Hp W	Lp P	Lp W	138	Lp	P	Hp P	Hp W	Lp P	Lp W
139	Lp	P	Hp P	Hp W	Lp P	Lp W	139	Lp	P	Hp P	Hp W	Lp P	Lp W
140	Hp	W	*	Hp W	*	*	140	Hp	W	*	Hp W	*	*
141	Hp	W	*	Hp W	*	*	141	Hp	W	*	Hp W	*	*
142	Lp	W	*	Hp W	*	Lp W	142	Lp	W	*	Hp W	*	Lp W
143	Lp	P	Hp P	*	Lp P	*	143	Lp	P	Hp P	*	Lp P	*
144	Lp	P	Hp P	Hp W	Lp P	Lp W	144	Lp	P	Hp P	Hp W	Lp P	*
145	Lp	P	Hp P	Hp W	Lp P	Lp W	145	Hp	P	Hp P	Hp W	Lp P	Lp W
146	Hp	P	Hp P	Hp W	*	*	146	Hp	P	Hp P	Hp W	*	*
147	Hp	P	Hp P	*	*	*	147	Hp	P	Hp P	*	*	*
148	Lp	W	*	Hp W	*	Lp W	148	Lp	W	*	Hp W	*	Lp W
149	Hp	W	*	Hp W	*	*	149	Hp	W	*	Hp W	*	*
150	Hp	P	Hp P	*	Lp P	*	150	Hp	P	Hp P	*	Lp P	*
151	Lp	P	*	*	Lp P	*	151	Lp	P	*	*	Lp P	*
152	Hp	P	Hp P	*	Lp P	*	152	Hp	P	Hp P	*	Lp P	*
153	Lp	W	*	*	*	Lp W	153	Lp	W	*	*	*	Lp W
154	np w		*	*	*	*	154	np		*	*	*	*
155	np		*	*	*	*	155	np		*	*	*	*
156	np w		*	*	*	*	156	np		*	*	*	*

* no seregation

APPENDIX 2

Individual plant data of F2 generation of the cross ICC 5716 x ICC 17101

PLOT	IPS	DFF	D50%	DFP	DM	HT	WD	PB	SB	NPP	Yld_P	NSP	HSW
1	7	50	52	57	105	38	33	2	6	101	17.4	152	11.44
1	7	50	52	57	107	32	29	3	4	140	20.4	162	18.02
2	10	48	51	58	103	37	29	3	4	105	13.9	118	11.77
2	10	48	51	56	106	27	24	3	6	88	12.8	162	12.59
2	10	48	51	56	106	30	26	2	4	102	15.6	132	11.81
2	10	48	51	56	106	28	29	2	1	95	12.4	105	11.8
2	10	48	51	56	106	34	35	2	4	121	15.6	136	11.47
3	11	49	51	58	106	30	40	4	2	90	11.2	105	10.66
3	11	49	51	58	104	34	33	3	7	101	14.8	126	11.74
3	11	49	51	58	105	34	24	3	2	82	12.5	102	12.25
3	11	49	51	58	104	43	40	1	4	203	24.9	203	12.26
3	11	49	51	58	104	38	38	5	2	124	18.1	145	12.48
3	11	49	51	58	104	38	29	2	3	134	17.9	156	11.47
4	11	41	48	49	102	33	34	4	2	128	19.1	153	12.48
4	11	41	48	49	104	41	30	3	8	102	15.7	124	12.66
4	11	41	49	48	107	23	20	2	3	55	6.7	66	10.15
4	11	41	49	48	102	33	31	3	3	105	11.3	116	9.74
4	11	41	49	48	105	38	33	3	6	127	18.2	147	12.38
4	11	41	49	48	107	34	31	2	3	55	7.8	72	10.83
4	11	41	49	48	107	32	27	3	5	132	20.5	169	12.13
4	11	41	49	48	107	30	27	4	5	80	11	96	11.45
5	10	49	50	56	105	38	32	2	4	100	13.5	120	11.2
5	10	49	50	56	107	35	30	2	4	12	16.2	134	12.08
5	10	49	50	56	107	27	29	1	4	86	11.1	105	10.57
5	10	49	50	56	107	32	29	2	2	74	8.9	85	10.47
5	10	49	50	56	107	37	33	1	4	152	28.8	226	12.74
5	10	49	50	56	105	30	32	2	6	135	21.6	190	11.36
6	12	49	50	58	107	25	20	2	3	24	3.8	29	13.1
6	12	49	50	58	104	30	28	5	2	95	13.8	130	10.61
6	12	49	50	58	108	32	31	3	4	90	12.3	103	11.94
6	12	49	50	58	108	30	29	2	4	110	15.9	143	11.11
6	12	49	50	58	108	33	37	3	4	185	25.9	220	11.71
6	12	49	50	58	108	28	30	3	5	124	18.2	152	11.97
7	10	50	54	57	106	39	34	3	7	114	17.3	151	11.45
7	10	50	54	57	109	25	31	2	6	102	14.6	125	11.68
7	10	50	54	57	109	24	26	3	4	55	8.9	76	11.71
7	10	50	54	57	109	36	33	2	5	113	15.6	128	12.18
7	10	50	54	57	109	37	33	3	7	100	19.8	105	11.97
7	10	50	54	57	109	30	31	2	5	115	1.6	135	11.55
8	12	49	51	58	102	32	27	3	4	120	17.8	150	11.86
8	12	49	51	58	108	32	35	3	5	85	11.9	106	11.22
8	12	49	51	58	102	22	18	2	1	19	3	21	14.28
8	12	49	51	58	107	32	31	2	5	203	24.4	193	12.64
8	12	49	51	58	107	40	39	6	7	124	18.5	137	13.5
9	11	42	47	48	101	34	30	2	5	101	14.8	115	12.96
9	11	42	47	48	105	32	23	2	1	54	7.5	62	12.09
9	11	42	47	48	105	33	29	3	6	145	19.3	165	11.69

9	11	42	47	48	105	33	30	3	6	123	18.1	162	11.17
9	11	42	47	48	105	30	25	2	3	58	7.5	67	11.19
10	10	48	56	56	107	30	29	3	2	60	7.9	63	12.53
10	10	48	56	56	107	31	29	2	4	86	10.5	84	12.5
10	10	48	56	56	107	35	30	2	4	111	15.7	118	13.3
10	10	48	50	56	107	36	31	3	4	114	14.7	139	10.57
10	10	48	50	56	107	34	33	3	7	80	12.2	98	12.44
11	10	48	49	58	109	34	28	2	4	115	16.3	148	11.01
11	10	48	49	58	106	30	26	4	2	55	6	56	10.07
11	10	48	49	56	107	31	25	3	7	58	8.9	67	13.28
11	10	48	49	59	107	27	22	3	1	62	9.4	73	12.87
11	10	45	46	53	106	38	32	2	4	127	20.7	176	11.76
12	10	49	49	58	103	40	30	2	4	131	17.8	148	12.02
12	10	49	49	58	105	24	23	2	1	47	6.4	56	11.42
12	10	49	49	56	106	27	23	3	2	41	5	42	11.9
12	10	49	49	56	106	29	30	3	4	85	11	94	11.7
12	10	49	49	58	106	40	30	3	4	87	11.4	100	11.4
13	12	45	46	53	108	27	20	2	2	65	9.1	78	11.66
13	12	45	46	53	106	33	35	1	2	120	17.7	151	11.32
13	12	45	46	53	106	25	21	3	4	84	11.2	99	11.31
13	12	45	46	53	106	32	30	2	3	189	21.5	201	10.69
13	12	49	49	58	106	30	25	2	3	141	19.8	188	10.53
14	11	41	44	48	102	33	31	3	5	132	20.5	169	12.13
14	11	41	44	48	107	31	29	2	3	107	14.3	132	10.75
14	11	41	44	48	105	32	28	4	7	171	18.5	148	12.5
14	11	41	44	48	105	30	25	2	4	94	13.6	113	12.03
14	11	41	44	48	105	33	49	3	4	102	13.2	122	10.81
15	9	45	46	56	109	31	27	2	5	118	16.3	136	11.98
15	9	45	46	53	104	30	30	3	3	72	10.9	97	11.23
15	9	45	46	56	104	33	30	2	3	177	27.1	199	13.61
16	11	49	51	56	101	34	27	2	4	121	14	144	9.72
16	11	49	51	56	104	31	27	3	6	150	19.4	180	10.77
16	11	49	51	56	104	35	20	4	2	54	7.5	55	13.63
16	11	49	51	56	104	23	26	2	2	134	18.2	160	11.37
17	9	48	52	57	105	33	24	3	4	123	18	165	10.9
17	9	48	52	57	108	30	29	3	4	86	10.9	101	10.79
17	9	48	52	57	108	23	20	3	1	22	3.1	22	14.09
17	9	48	52	57	108	28	24	3	4	47	7.8	64	12.18
18	11	42	49	49	100	34	25	2	4	112	9	87	10.34
18	11	42	49	49	105	40	44	3	8	202	42.6	361	11.8
18	11	42	49	49	106	31	30	3	5	154	21.8	198	11.01
19	15	49	51	57	106	35	34	1	3	169	26.7	220	12.13
19	15	49	51	57	104	30	29	3	4	99	11.9	97	12.26
19	13	49	51	57	106	29	18	2	2	55	5.8	53	10.94
19	13	49	51	57	106	32	28	3	4	105	16.4	123	13.33
19	15	49	51	57	106	37	34	4	3	80	11.4	97	11.75
20	10	46	49	53	107	30	29	3	7	110	18.6	154	12.07
20	10	46	49	53	107	35	28	4	2	72	9.8	81	12.09
20	10	46	49	43	107	40	32	3	4	105	13.8	125	11.04
20	10	44	46	49	107	28	25	1	3	55	8	81	9.87

APPENDIX 3

Individual plant data of F3 generation of the cross ICC 5718 x ICC 17101

E no	IPS	DFF	D50 %F	DFP	DM	HT	WD	PB	SB	NPP	Yld_P	NSP	HSW
2	9.5	45	49	53.5	107	36.5	27.65	2.8	5.1	91.5	13.15	106.1	21.25
3	10.5	45.5	50	53	107.5	36.7	30.2	3.7	4	97.7	13.6	133	12.45
4	9.5	47	49	56.5	109	35	31.2	3	4.2	116	13.5	131.5	10.03
5	9.5	45.5	49	57.5	108	32.8	30	2.8	3.8	89.8	11.76	96.1	12.26
6	9.5	48.5	505	58.5	104	34	24	2.5	4	84	11.25	99	11.34
7	9	48.5	505	58	106.5	34.5	26	3.5	4.5	111.5	16.75	141.5	11.81
8	9.5	45	48.5	52.5	105.5	36.5	29.5	3.7	6	136	19.67	166.7	12.95
9	10.5	47	51	54.5	104.5	34.2	25.2	2.7	5.5	94.7	14.55	109.5	13.77
10	9.5	48.5	50.5	56.5	102.5	37	34	4	5.6	96.2	13.35	107.2	12.49
11	11	42	50	49	104.5	34.5	26.2	2.5	4.7	99	15.57	132.2	11.88
12	8.5	46	50.5	57	105.5	31.2	27.7	2.7	5.5	82	11.2	94.2	11.99
13	9.5	49	50	58	106	36	33.2	3.5	4.5	123.2	17.5	141.5	12.37
14	10	45.5	50.5	52	105	36.7	30.75	3	4.2	82.5	19.65	156.2	11.35
15	3.5	55	60.5	67.5	109	31.5	30	3	4	83.5	11.75	92.5	12.41
16	8	45	50.5	62.5	107	39.7	26.25	3.2	5.7	102.7	16	132	12.24
17	6	45.5	47	52	108	36	31	2.5	5	130	15.85	140.5	11.56
18	7	51	54.5	59.5	110.5	39.2	34.2	2.7	5.2	109.7	14.45	117.2	12.17
19	7.5	47.5	50	54	106	36	21.5	2.5	7	82.5	13	117	10.6
20	10	46.5	505	56.5	103.5	38	35.1	2.5	5.5	136.5	18.4	137	13.28
21	9.5	45	47.5	52	105	40.7	29.7	3.7	5.7	111.7	16.3	129.2	11.91
22	7.5	46	49.5	57.5	108.5	36.5	28.5	3	6.5	110	14.85	126	11.97
23	9.5	47.5	49	58	106.5	34.5	29.1	2.6	4.6	115.9	17.4	146.5	11.91
24	10.5	49.5	52.5	58.5	106	33.7	28.2	2.5	4.7	88.5	12.07	92	13.45
25	9.5	42	48	49.5	108.5	31	19	3	5.5	81	11.5	101	11.37
26	9.5	45.5	46	52.5	104.5	34.5	31	2.5	5	99.7	15.47	132.7	11.63
27	9.5	49	57.5	56	108	32.5	26	3	4.5	88.7	14.2	108.7	13.72
28	7.8	49	52	57	108	37.2	31.2	3.2	5.2	99.2	13.45	110.7	13.2
29	7.5	48.5	50.5	58	104.5	35.5	32	3.2	4.5	141.5	18.17	151.8	11.97
30	10	51	52	58.5	108	35.2	30	3.5	6.2	113.7	17	138.5	11.48
31	7.5	43	46	52.5	104.5	33.7	26.5	3.2	5.7	96.5	15.25	125.5	12.41
32	11	42	47.5	48.5	101.5	37	28.2	3.5	4.7	101.5	15.37	124.5	12.91
33	9.5	47	51	57	107.5	36	26.2	3	4.5	96	13.5	109.2	12.36
34	10	47.5	49.5	54	104	40	36.5	3.5	6	115.5	17.7	144	12.24
35	8	49.5	54	58	105	28.2	22	3.5	6	91.2	12.02	99.25	12.01
36	9.5	45	49	53	107.5	34.5	24.7	3.5	4.7	92.5	12.87	120	12.1
37	10.5	44	49	53.5	106	34.2	28	2.7	6.2	91.7	13.12	110	11.92
38	9.5	48.5	51	57.5	105.5	36.5	23.7	3.7	4.5	91.75	11.75	93.7	12.54
39	8.5	45.5	50	54	107.5	36.4	27.4	3.5	5.3	95.6	15.36	106.3	14.1
40	9.5	48	50	56.5	107.5	35.2	29.2	3.2	4.7	214	20.72	183.5	11.62
41	9	50	51.5	59.5	105.5	35.5	28.5	2.7	6	124.2	17.3	154.7	11.37
42	8.5	48	50.5	58	102	37	31	3	4.5	125.5	12.35	151	11.48
43	9	45	49.5	53	105	41	32.5	2.5	6	116	16.45	132.5	12.44
44	8	45.5	47.5	53	104.5	34.2	29.2	2.7	5.5	91.7	15.82	108	14.89
45	7	46	51	56.5	106.5	32.5	27	3	5	88.2	13.25	102.5	12.83
46	8.5	52	53	60	110	43	30.2	3.2	6.5	133.2	21.42	149.2	14.31
47	10.5	42	47.5	48	105.5	37	22.7	3	5	93.5	13.27	86.7	12.68
48	9.5	44	49.5	53	106.5	39.5	30.5	3.5	4.5	136	20.65	165	12.53
49	10	43	48.5	50	107	38.3	26.1	3.1	5.8	110.1	15.48	132.3	11.39
50	9.5	46	49.5	54	103	36.5	31.5	3.2	6.5	129.3	18.67	162.5	11.36
51	10.5	48.5	50.5	57	107	35	26.25	2.7	6.5	103	14.02	110.7	12.55

52	10.5	45.5	50	47.5	106	39.5	27.5	3	7.5	99	16	128	12.25
53	6.5	46.5	50.5	53	104	37	35	4.5	12.2	153.8	21.27	185.7	11.36
54	3.5	58	64.5	65	111	40.5	32	3.5	7	113	17.4	126	13.79
55	10	42.5	45	52	105	34	29.5	2.5	5	103.5	16.7	118	11.57
56	10	51.5	49.5	54.5	106.5	38	30.2	3.2	6.7	106.5	19	157	12.01
57	9	43	48	50.5	106	36.5	30.3	3.4	6	126.5	16.81	139.1	12.23
58	9	50	51.5	57.5	106	36.6	33.5	2.9	3.6	83.6	11.55	96.33	12.36
59	7.5	49.5	51.5	59	105	36	28	3.5	5.5	88.5	13.25	105	13.91
60	10	42	47.5	49.5	107	39.2	30.7	3.7	6	96.7	14.65	118.7	12.34
61	8.5	48	51.5	58.5	102.5	38.5	36.7	3	4	103.2	14.32	119	13.14
62	8	47	49.5	58.5	108.5	31.8	26.4	2.3	5.2	89.3	11.6	105.9	11.64
63	7.5	45	49	52	108	35.7	31	3	5	113.2	14.75	132.6	11.1
64	8.5	48.5	51	56.5	106.5	34.9	24.3	2.6	6.8	83.15	12.18	98.1	12.34
65	8	50.5	54	59.5	107.5	33.5	33	3.5	6.5	132	19.35	167.5	11.66
66	9	42.5	47.5	48.5	107.5	38.5	31.5	2.5	6	121	19.3	151	12.92
67	10.5	45.5	50	52.5	103	32.4	23.5	2.2	4.9	93.4	12.15	109.6	10.44
68	9	42	46	46	105.5	33	25.7	3	5	96.7	13.77	116.5	12.08
69	10.5	41.5	45	49	108	34.7	24.7	2.5	4.7	99.5	12.9	110	12.1
70	9.5	45.5	50	52.5	106.5	33.7	28	3.7	5	109.8	14.5	123.5	11.67
71	10	45.5	51	53	107	37.7	30.5	3.7	7.2	93.2	14.17	112.5	12.78
72	10	48	51	57	109	36.8	29	3.6	6.1	121.4	17.64	144.4	12.2
73	9	46.5	50.5	53.5	104.5	35.7	26.2	2.7	5.5	90	12.52	97.7	12.46
74	10.5	49.5	52	58	108.5	36	23	3.2	7.5	128.5	15.6	128.5	12.49
75	10	42	45.5	48.5	107	37.5	33	3.5	6	103.5	14.55	120.5	12
76	8	46.5	46.5	56	106.5	34.3	27.7	3.7	6	108.7	15.67	131.5	12.42
77	8.5	49	51	57.5	108.5	37	24.5	3.5	10.2	107	15.15	128	11.82
78	9.5	41	46.5	49.5	107.5	35.5	30.2	3.7	4.5	80.7	19.07	160.5	11.84
79	10.5	45.5	50	54	106.5	33.6	28.8	3.3	5.1	107.1	14.66	127.5	12
80	9	42.5	48	49.5	101.5	37.5	30.5	3.5	7	139.5	20.7	182	11.39
81	10	41	49	49	108.5	38.7	28	3.2	5.7	93	13.32	105.7	12.61
82	9.5	48.5	51.5	56.5	108.5	35	30.8	3	6.8	137.8	20.15	168.6	12.04
83	10	43.5	50	53	103.4	34	31.1	2	2.5	86.4	11.2	104.7	11.174
84	9	42	45	48.5	104	41.2	34.2	3.7	5.7	144	21.42	178.2	12.15
85	8.5	46	47.5	53.5	109	40	29.5	3	5	172.5	26	211	12.3
86	10.5	46	51.5	53	107.5	38.7	35.7	4	6.5	108.1	16.45	130.6	12.34
87	10.5	46	45	52.5	104.5	37.5	29.2	3	5.7	114.7	16.21	147	11.74
88	8.5	47	50.5	54	104.5	34	30.5	3.5	6	106	13.2	107	12.88
89	8.5	46	50.5	56	107	36	28	3.5	5	132	20.6	157.5	13.07
90	10.5	49	52	57.5	106	38.7	34.2	5	4.7	106.2	16.7	117	14.3
91	9.5	46	48.5	56	102.5	31	23	2.7	6	101.5	14.1	110	12.61
92	8.5	54.5	50.5	54	108.5	35.2	31	4.2	7.2	131.5	16.35	160.5	11.77
93	10	46	49	53.5	102.5	33.5	28.5	2.5	3.5	115.5	15.3	149	10.58
94	10	49	51	57.5	102.5	38	29	3	4.5	121	17.2	140.5	13.2
95	8	45.5	50.5	53	106.5	37.3	28.7	3.5	6.1	143.7	20.56	167.7	15.61
96	9.5	50	53	57.5	106.5	41.5	32.5	4	6.5	124.5	17.4	139.5	12.55
97	10	48.5	50.5	57	106.5	35.1	29.8	3.7	4.7	102.1	15.59	127	12.32
98	7.5	45	51	54	108	36	27	2.8	5.6	90	12.43	113.5	11.01
99	9.5	43	50.5	51	105.5	31.5	23	2.2	3.5	115.2	14.12	122.7	11.47
100	8.5	43.5	49	52.5	108.5	36.2	28	3	5.5	150.7	18.17	161.2	11.21
101	9	45.5	50	53.5	106	43.9	31.5	3.6	6.8	161	21.6	159.4	12.87
102	10.5	48	50	57	105.5	39	33.7	2.7	5.2	118	16.1	128.7	12.5

103	9	45.5	50.5	55	107	36.2	25	3	5.5	67.25	9.52	75.7	12.61
104	9	41.3	52	50	107.5	34	26.7	3.4	5.5	102	15.07	117.2	12.51
105	11	46.5	50	56	103	38	31.5	3	5	117.5	17.65	135.5	12.82
106	10.5	44	48.5	53	108	34.2	25.7	3.7	5.2	111.5	14.55	127.5	11.54
107	10	42	47.5	48.5	105.5	35.5	25	2.5	6.5	93	12.1	151.5	11.87
108	8	50.5	54	57.5	108	37	28.7	3.5	5.2	119.5	15.32	122	12.52
109	8	44	48.5	53.5	105	33.7	39	3.7	5	100	14.45	125.7	11.65
110	10.5	43	44	52.5	104.5	39.5	32.5	2.5	5.5	91	21.7	167.2	13.1
111	6.5	46	51	57.5	109.5	31	27	2.5	4	97	12.75	108.5	12.72
112	9.5	45	48.5	53	106	35	25.2	2.7	6.5	104.7	14.82	129.5	11.42
113	11	47	50	57	106.5	36.7	33.5	2.7	5	131.2	15.95	77.25	12.39
114	9	49	51	57	106	37.2	30	3.7	5.5	117	16.95	142.5	12.08
115	10	48	51	57	107	34.2	28.8	3	5.1	98.87	13.45	101.3	13.48
116	9	45	50	52.5	104.5	37.4	27.5	3.5	7.05	115	17.17	131	13.09
117	8.5	45.5	49.5	52	107.5	31.7	24.7	2.5	5.5	99.75	13.65	112.2	12.12
118	7.5	41.5	50	57.5	102.5	34.5	32	3	4.5	98.5	14.55	115.5	13.21
119	8.5	50.5	52.5	59	107	34.2	28.7	2.2	4.2	104.2	14.6	132	11.8
120	7	47	53.5	53.5	107.5	43.5	64.5	4.5	5.7	130	19.4	162.5	11.96
121	9	45.5	50.5	54.5	103.5	36	28	4	6.5	108	16.85	137	12.32
122	10	46.5	54	54.5	104.5	35.2	29.5	3.2	5	78	10.75	84.75	12.76
123	9.5	50.5	51	58	106	37	24	3.5	6	81	11.7	93	12.66
124	7	49.5	52	57.5	104.5	33	28	3.5	5.2	105	14.22	104.7	12.03
125	10.5	42.5	50.5	50	109	35.8	25.6	2.9	7	91.1	15.76	67.8	12.08
126	8.5	48	51.5	58	105	37.5	28	4	4.5	97.5	12.95	111	11.76
127	9	43.5	48.5	50	106.5	34.6	28.9	3.8	5.5	129.5	17.82	147.1	12.43
128	7	45.5	49.5	54	107.5	36	25.5	2.8	5	100.6	14.46	111.3	12.52
129	8.5	45	50.5	53	103	43.5	39	3	7	154.5	24.35	188	12.29
130	9	49.5	51.5	58.5	108.5	34.7	28	2.5	4.7	100.6	14.65	111.5	12.49
131	10	45	49	51	103	32.1	30.3	2.6	2.9	122.3	16.7	147.5	11.34
132	8.5	48.5	50.5	58	104	36.5	39.2	2.8	6.1	102.1	14.25	116.2	12.91
133	7	46.5	51.5	56.5	105	30	22.7	3	5.2	96.2	13.92	111.5	12.51
134	8.5	43	48.5	57	107.5	37	34.7	3.2	6.5	130.7	23.3	186.2	12.2
135	8.5	49	51	56.5	104.5	34	28.2	2.7	5.5	99.2	12.7	128	11.56
136	9.5	49	50.5	56	105	38.2	31.7	3.2	4.7	89.7	13.52	105	12.93
137	9.5	49	50.5	57	101.5	34.3	29.5	2.8	4.6	83.4	11.13	55.98	12.76
138	9	41.5	47	48.5	104.5	34.4	27.1	3.1	4.6	100.3	14.84	128.7	11.65
139	10.5	47.5	50	55.5	107	38.1	29.6	3.2	6	120.9	16.76	139.5	11.84
140	10	45	46.5	52.5	10.5	36.5	30.5	3.5	4	117	17.85	121	14.51
141	11	44	48	51.5	103	29.5	24.5	2	4	60	8.5	72	11.81
142	9.5	50	52	55.5	105.5	55	33.7	3.5	4.5	136.7	19.32	171.5	11.57
143	10	49	50.5	57	109.5	38	31.7	3.2	4.5	116	16.25	137.2	12.34
144	8.5	42	50.5	57	107	35.4	30.8	3.1	8.5	146.5	18.72	153.9	12.18
145	8	45.5	51	53.5	104	39.5	26.4	3.5	6.2	121.4	17.49	135	12.94
146	10.5	45	48.5	52.5	103	38.5	31.5	2.2	5.8	95.5	14.52	120.2	12.06
147	10	48.5	50.5	56	103.5	35.5	36.5	4	5	139	18.8	165	11.31
148	8.5	43	49	53	108	32.2	26.7	2.5	5	80	11.07	96.5	11.91
149	8	49.5	50.5	58	103.5	41	30	3	5.5	168	25.45	184.5	14.47
150	9	47.5	51	55.5	105.5	36.5	26	2.5	6	110.2	14.85	128.5	11.56
151	6.5	44	48	52.5	105	31	27.7	3.7	5.5	81.2	11.32	89.75	12.6
152	9.5	45.5	51	56.5	104.5	34	27	2.8	5.7	94.3	13.1	120.1	12.18

APPENDIX 4

Individual plant data of different genotypes for white flower colour

E no	IPS	DFF	D50%	DFP	DM	HT	WD	PB	SB	NPP	Yld /P	NSP	HSW
1	8.5	47	59.5	49	113.5	44	40	4.5	4.5	96.5	100.5	47.1	22.35
2	7.5	33.5	42.5	41	107.5	34	35.5	3	4.5	83.5	95	21.15	22.33
3	7.5	38	46	46	111.5	40.5	36.5	45	4.5	8.5	85	17.95	20.02
4	8.5	42	50.5	49.5	111	32	29.5	4.5	4.5	69	95.5	16.15	16.79
5	10.5	30	49	35.5	111	33	31	3	2.5	46.5	44.5	9.5	21.49
6	5.5	51	62	58	113	38.5	44	5	2	108	131	18.85	14.43
7	8.5	66	70.5	76	113.5	46.5	36	3.5	4.5	76	72	10.85	12.36
8	8.5	30	38	37	109.5	35.5	31	2.5	2	72	78.5	14.7	19.24
9	8.5	33	43.5	39.5	115	41	33	2.5	5.5	105	114.5	20.7	18.98
10	10	30	33	37	109	34	29	2	1	555	53.5	10.75	21.31
11	10	38	47	47	113	33	31.5	3.5	3	755	82	12.45	14.31
12	9.5	27.5	34.5	33.5	109.5	28	30.5	3.5	3	565	54	12.5	23.16
13	5	49.5	51	57	113.5	44.5	47	6.5	5	58	74	8	10.93
14	6	27.5	50.5	33	111	43.5	38	4	4	126	133.5	22.95	33.73
15	8	29.5	40	36.5	109	35	29.5	2.5	3	49	48.5	8.1	19.47
16	6	36	52.5	43	112.5	42	34	4	2.5	77.5	76.5	12.55	16.48
17	8.5	36	48	42.5	114	33	26.5	3	3	58	70	10.2	14.92
18	9	64.5	72.5	73	113.5	49	42	35	7.5	105.5	104	15.92	15.38
19	6	48	51	56	110	40	36.5	4	3.5	88	96	16	15.05
20	9	48	51	56	110	40	40.5	4	3.5	88	96	16	15.05
21	10	48.5	60.5	55.5	106.5	40	33.5	5	4.5	101.5	106.5	17.75	16.85
22	10	27	32.5	33	110	23.5	32	2.5	1.5	37.5	405	7.25	18.01
23	8	50	57	57.5	113.5	49.5	44	3.5	8	69	705	12.05	17.2
24	9.5	56.5	66.5	64	111	35.5	35.5	3	4.5	85	100.5	16.3	16.73
25	8	43.5	49.5	52.5	110	40	34.5	3	3.5	92.5	100.5	16.35	16.22
26	10	60.5	70	69.5	111	42	35.5	2.5	4.5	76.5	75	12.05	16.55
27	7	34	42	37.5	112	42	36	3	3	79	78.5	14.1	18.21
28	8.5	46.5	66.5	53	111.5	48.5	46	4	7	102.5	113	17	15.19
29	9	60.5	50	38	110.5	45	39.5	3	6	20.6	120	31.15	20.9
30	6	30	44.5	36.5	110	44.5	38	3	2.5	82.5	765	15.42	20.52
31	8.5	26	34	33	110.5	40	40	5	5.5	137.5	118	16.25	10.35
32	7	35.5	62	41.5	113	50.5	48	4	5	119	110	21.05	19.75
33	6	36.5	56	43.5	110.5	45	39	3.5	5	137	138	20.7	15
34	7.5	40	56.5	47	113	39	38	3	2.5	665	635	12.45	18.9
35	7	38	465	45	111	29.5	31.5	3	2.5	65	183	16.5	19.09
36	11	45	55.5	52.5	112.5	40.5	39	2	3	81	81.5	16.5	20.03
37	9.5	31	50.5	37.5	111.5	35	34.5	3	2.5	72.5	68.5	15.2	22.9
38	8.5	32	42	39.5	109	36	33	2.5	3.5	115.5	136.5	21.1	15.61
39	11	34.5	48.5	40.5	111	35.5	34.5	4	4	67.5	62.5	10.43	22.77
40	10	37.5	45	45	109.5	30.5	30.5	3	3.5	106.5	64.5	13.1	20.48
41	8.5	36	45	43	112.5	38	33.5	3	2	91	100	15.95	15.73
42	9.5	41.5	51	48.5	111.5	43	45.5	4	4.5	215	118	18.3	15.29
43	8.5	31	50	37.5	111	46	45	3.5	2.5	86	85	16.55	19.8
44	6	32	38	37.5	107.5	30	32.5	2.5	2.5	71.5	95	15.25	17.32
46	9	43	65	51.5	111.5	31.5	31.5	4.5	3.5	91	86.5	20.15	23.33
47	4.5	31.5	44	37	110.5	30.5	30	3	4	96	87.5	12.45	10.72
48	6.5	29	47	36	108.5	36.5	38.5	2	4	62.5	60	13.2	22.06
49	7	26.5	34	33.5	113	50	48.5	4	4.5	131	91	12.65	137
50	9	48	51.5	55.5	112	40	34	4	3.5	61.5	74.5	9.8	14.78
51	8	29	34	35	108.5	27	26	2	1.5	45	40.8	8.1	19.58
52	9	52	63.5	59.5	111	46	42.5	4	7.5	197	188	33.85	19.07

53	5.5	30	41	36.8	110.5	36.5	30.5	4	3.5	123	106.5	13.5	12.63
54	6	37.5	46	44	109.5	36.5	37.5	4	4.5	104	121.5	19.25	15.87
55	9.5	41	59	48.5	112.5	37	41	4	6.5	112	111	14.8	13.85
56	8.5	27.5	56	34.5	109	36	32	4.5	2	91.5	81.5	12.35	15.2
57	10	46	53	53	112	35.5	35.5	4	3	70.5	64.5	73	11.28
58	8.5	42	55.5	99.5	113	46	43	3.5	6	93	89	13	15.15
59	7	27.5	56	34.5	109	36	32	4.5	2	91.5	815	12.35	15.2
60	9	31	38.5	39.5	109.5	33	30.5	2.5	5	89	102	17.9	17.02
61	9.5	40.5	61.5	48	114.5	39.5	34.5	3.5	2	66	70	12.25	14.5
62	10.5	56.5	71.5	66	114	47.5	53	4.5	8	139.5	129.5	22.8	17.54
63	8.5	34.5	48.5	42	114.5	39	41.5	5	6.5	123.5	72	9.6	13.39
64	10	28.5	38.5	36.5	110	30.5	32.5	3	2.5	76.5	65.5	13	19.83
65	11	26	33	31.5	107.5	24	28	2.5	3.5	85	80.5	13.3	16.53
66	7.5	29.5	35.5	36	105.5	36.5	37.5	3.5	3	99.5	115	21.65	18.34
67	9.5	29.5	35.5	37	109.5	37.5	33.5	3.5	1.5	83.5	82.5	19.6	23.72
68	9	33	50.5	39	110.5	44	41	3.5	3	79	50	9.1	17.17
69	8.5	30	46.5	35.5	111	33.5	27.5	2.5	1.5	52.5	54	99	17.63
70	9.5	31	42.5	31	108.5	35	32.5	2	4	104.5	101.5	15.15	17.87
71	9.5	28	41.6	34	111	33	32	4.5	5	140	106	24.55	15.89
72	8	29.5	40.5	38	110.5	39	31	2.5	4	100	101	17.9	17.78
73	7.5	40	50.5	48	112	33	34	2.5	4	97.5	103.5	16.5	16.08
74	10	32.5	38.5	41	109.5	49.5	46.5	3.5	7.5	181	144	17.75	12.75
75	4	32.5	47.5	39	109.5	36.5	37	3.5	3	125	136.5	231	16.74
76	8.5	61.5	67	70.5	111.5	43	44	4	5	106	125.5	15.6	13.77
77	8.5	39	57	45.5	112.5	30	26.5	3	3.5	94.5	79	12.6	15.29
78	9	38	48	45	111.5	34	32.5	3.5	3.5	110	106	17.75	16.75
79	8.5	30.5	45	36.5	114.5	39.5	32.5	3.5	5	99	114.5	17.7	15.45
80	6.5	30.5	38.5	36.5	109.5	30.5	32	3	4	98.5	99	15.85	16.44
81	9.5	36	41.5	42	105	32.5	36	3	3.5	140	141.5	22.88	16.11
82	6.5	30	40	36.5	113	39.5	36	4	3	113.5	129	18.05	13.8
83	9.5	31	41	38	110.5	37	32	3.5	3	40	47.5	4.45	10.7
84	10.5	36	57.2	42.5	112.5	43.5	35	5	4	96	60.5	9.75	15.72
85	9.5	50.5	63.5	57.5	111.5	32	37.5	2.5	3.5	76	122	17.35	14.27
86	3.5	40	56.5	51.5	112	38.5	40	3.5	5	162.5	145.5	22.3	15.09
87	10	40	53.5	47	111	32.5	31.5	3.5	2.5	65	79	13.3	13.83
88	8.5	37	54	42.5	112.5	31	40	2.5	5	104.5	118.5	18.3	15.64
89	9.5	40.5	55	53.5	115.5	41	40	3.5	3	203.5	88	13.75	15.81
90	7.5	33.5	45	40.5	110.5	38.5	33.5	3.5	4	112	128	19.1	13.53
91	9	34.5	44	46.5	109.5	44	36.5	2.5	4	79	92	16.45	117.6
92	6.5	33	45	39	104.5	37.5	25	3	3.5	98.5	115.5	16.6	14.45
93	8.5	31.5	46.5	38	109	36	32	3	3	96.5	115	14.9	12.97
94	10	28	35	34	111	35	23	2.5	2.5	54	67	11.3	16.89
95	9.5	45	51.5	31.5	110	39.5	33.5	3.5	4	121.5	153.5	23.2	15.18
96	8.5	27	40	34	112.5	47	41	4	4.5	167.5	180	29.15	16.27
97	9.5	65.5	69.5	74	112.5	50	41.5	2.5	3	57.5	54.5	10.95	20.06
98	7.5	31	42	38	108.5	38	36.5	2	3.5	79.5	87	19	21.61
99	7	26.5	31.5	34	108.5	34.5	30	3	2	85.5	91	17.45	18.07
100	10.5	30	40.5	37	108.5	32.5	25	3.5	3	95.5	113	15.25	13.01
101	9.5	30	43	36.5	111.5	42	44	4	6	180.5	190	27.2	14.33
102	8	42	50.5	48.5	109.5	35.5	40	5	6.5	197.5	206	28.55	13.65
103	6.5	46	52	53	112.5	195	30.5	2.5	3	91	99.5	14.05	14.45
104	9	30.5	45	36.5	114.5	39.5	32.5	3.5	5	99	114.5	17.7	15.45
105	10	50.5	63.5	56.5	114.5	38.5	41.5	5	4.5	139	128.5	14.85	13.14
106	7	51.5	56	58.5	109	42.5	34.5	3	3.5	82	82.5	12.05	15

107	7.5	48	52.5	54.5	114.5	39.5	36.5	2.5	4	148	148	21.35	14.83
108	7.5	49.5	50	57.5	111	41	39	3.5	4.5	73	75.5	13.25	17.94
109	9	37.5	51.5	45	112	36	30	3.5	2.5	46	45	7.8	17.25
110	11	41.5	49	48.5	109.5	39	29.5	3	2.5	76.5	94	12.1	13.39
111	7.5	51	57	60	110.5	38.5	36.5	4	2	64	73.5	15.35	21.01
112	8	36.5	47.5	44.5	109	29	27.5	3	2.5	73.5	92.5	12.45	13.4
113	7	52	53	59	111	44.5	41.5	5.5	6	125	91.5	14.4	16
114	9.5	41.5	46.5	49.5	107	35	35.5	4	5.5	176	188	26.25	13.67
115	9.5	44	49.5	52	109.5	39.5	32.5	3.5	5	99	114.5	17.7	15.45
116	6.5	49.5	57	57	110.5	42	41	4.5	3.5	110	112	14.85	13.14
117	10	42.5	51	50	112	39	37.5	3	4.5	72.5	66	12.9	19.09
118	9.5	45.5	52	53.5	112	36.5	36	3.5	4.5	88.5	86	22.25	28.1
119	10	47.5	53.5	55.5	110	41	39	2.5	5.5	115	118.5	17	14.21
120	9.5	36	51.5	43.5	112.5	41	39	2.5	6	79.5	78.5	20.35	24.06
121	8	49.5	54	56	109.5	37	27.5	3	3	80	78.5	15.65	21.29
122	8.5	49	51.5	56	111	45	38	4.5	3	44.5	47	6.1	13.13
123	7.5	50	57.5	57	111.5	42	34.5	4	2	76	69	14.95	21.47
124	8.5	41.5	50	49	110	38	37	3.5	5	79	86	15.5	17.98
125	10	40.5	46.5	47	111	35.5	36.5	5	4	98.5	116.5	19.1	16.2
126	6	39	44.5	47.5	109.5	40	38.5	4.5	8.5	97.5	102.5	21.65	21.18
127	4	58.5	63.5	67.5	112	42.5	40	2.5	7.5	160	152.5	33.85	22.38
128	6.5	49.5	53	58	108.5	41.5	37.5	3.5	4	87.5	42.5	14.95	11.24
129	10.5	44	49.5	56	110.5	41.5	39	3.5	4	83	70.5	19.6	22.51
130	9	44.5	51	52.5	111	35	39.5	4.5	4	89	80.5	12.15	14.77
131	8	44.5	49.5	53	104	42.5	39	4	4.5	82.5	87.5	20.65	22.78
132	8	53	56	59	111	46.5	31.5	4.5	5	79.5	64.5	11.65	16.69
133	8	39.5	50.5	47.5	108.5	39.5	40.5	4.5	2.5	92	74.5	16.65	22.32
134	7.5	36	47	48	109.5	38.5	34	2.5	3	145	178.5	23.35	13.11
135	10.5	40	42	46.5	110	31	36.5	3.5	4.5	125	133	19.9	14.87
136	9	54.5	59.5	60.5	111.5	36	33.5	3	5	84	99	14.2	14.68
137	9	42	50.5	49	112.5	33.5	36.5	2	5.5	74.5	85.5	11.95	14.81
138	10.5	44	52	52.5	112	34	38	3	4	123	149	13.35	8.78
139	9	40.5	42	48	111	32	34.5	3	5	107	132	16.55	12.39
140	8	48.5	51	57	112	32	30.5	4.5	2	108.5	118	17.7	15.3
141	7.5	40	47.5	47.5	114	38	44.5	3	3.5	9.3	94	12.35	12.86
143	8.5	48.5	56.5	55.5	112	48.5	37	3	4	129	128.5	168	13.36
144	7	48	42.5	55.5	111	42.5	37.5	4	5	155.1	143	20.3	14.36
145	7	41	45.5	48.5	114	40	43	4	3.5	136	151.5	20.3	13.38
146	9	58	61	65	113	45	46.5	6	2.5	144.5	124	124	9.68
147	7.5	60.5	84.5	69.5	114	40	41.5	4	5.5	200.5	156.5	14.9	10.85
148	10	30.5	35	37.5	110	30.5	25	2	2	48	49	108	22.11
149	9.5	70	78	78.5	114.5	43	33	4	5.5	119	129	15.65	13.86
150	8.5	36.5	33	37.5	107	35.5	36.5	2.5	2	89.5	88.5	20.3	23.43
151	9	30	34	37	113.5	31	26.5	2.5	2.5	8.2	86.5	18.25	18.25
152	8.5	34	41	41	108.5	35.5	33	25	2.5	87.5	87	164	19.01
153	8	38	41	44	108	38.5	30.5	2	1.5	94.5	101.5	23.8	23.31
155	8.5	52.3	59.5	59.5	110	41.5	43	4.5	6.5	120.5	100	21.3	21.34
156	7	44.5	50.5	52	111.5	40.5	39	3.5	3	62	59.5	13.35	22.41

107	7.5	48	52.5	54.5	114.5	39.5	36.5	2.5	4	148	148	21.35	14.83
108	7.5	49.5	50	57.5	111	41	39	3.5	4.5	73	75.5	13.25	17.94
109	9	37.5	51.5	45	112	36	30	3.5	2.5	46	45	7.8	17.25
110	11	41.5	49	48.5	109.5	39	29.5	3	2.5	76.5	94	12.1	13.39
111	7.5	51	57	60	110.5	38.5	36.5	4	2	64	73.5	15.35	21.01
112	8	36.5	47.5	44.5	109	29	27.5	3	2.5	73.5	92.5	12.45	13.4
113	7	52	53	59	111	44.5	41.5	5.5	6	125	91.5	14.4	16
114	9.5	41.5	46.5	49.5	107	35	35.5	4	5.5	176	188	26.25	13.67
115	9.5	44	49.5	52	109.5	39.5	32.5	3.5	5	99	114.5	17.7	15.45
116	6.5	49.5	57	57	110.5	42	41	4.5	3.5	110	112	14.85	13.14
117	10	42.5	51	50	112	39	37.5	3	4.5	72.5	66	12.9	19.09
118	9.5	45.5	52	53.5	112	36.5	36	3.5	4.5	88.5	86	22.25	28.1
119	10	47.5	53.5	55.5	110	41	39	2.5	5.5	115	118.5	17	14.21
120	9.5	36	51.5	43.5	112.5	41	39	2.5	6	79.5	78.5	20.35	24.06
121	8	49.5	54	56	109.5	37	27.5	3	3	80	78.5	15.65	21.29
122	8.5	49	51.5	56	111	45	38	4.5	3	44.5	47	6.1	13.13
123	7.5	50	57.5	57	111.5	42	34.5	4	2	76	69	14.95	21.47
124	8.5	41.5	50	49	110	38	37	3.5	5	79	86	15.5	17.98
125	10	40.5	46.5	47	111	35.5	36.5	5	4	98.5	116.5	19.1	16.2
126	6	39	44.5	47.5	109.5	40	38.5	4.5	8.5	97.5	102.5	21.65	21.18
127	4	58.5	63.5	67.5	112	42.5	40	2.5	7.5	160	152.5	33.85	22.38
128	6.5	49.5	53	58	108.5	41.5	37.5	3.5	4	87.5	42.5	14.95	11.24
129	10.5	44	49.5	56	110.5	41.5	39	3.5	4	83	70.5	19.6	22.51
130	9	44.5	51	52.5	111	35	39.5	4.5	4	89	80.5	12.15	14.77
131	8	44.5	49.5	53	104	42.5	39	4	4.5	82.5	87.5	20.65	22.78
132	8	53	56	59	111	46.5	31.5	4.5	5	79.5	64.5	11.65	16.69
133	8	39.5	50.5	47.5	108.5	39.5	40.5	4.5	2.5	92	74.5	16.65	22.32
134	7.5	36	47	48	109.5	38.5	34	2.5	3	145	178.5	23.35	13.11
135	10.5	40	42	46.5	110	31	36.5	3.5	4.5	125	133	19.9	14.87
136	9	54.5	59.5	60.5	111.5	36	33.5	3	5	84	99	14.2	14.68
137	9	42	50.5	49	112.5	33.5	36.5	2	5.5	74.5	85.5	11.95	14.81
138	10.5	44	52	52.5	112	34	38	3	4	123	149	13.35	8.78
139	9	40.5	42	48	111	32	34.5	3	5	107	132	16.55	12.39
140	8	48.5	51	57	112	32	30.5	4.5	2	108.5	118	17.7	15.3
141	7.5	40	47.5	47.5	114	38	44.5	3	3.5	9.3	94	12.35	12.86
143	8.5	48.5	56.5	55.5	112	48.5	37	3	4	129	128.5	168	13.36
144	7	48	42.5	55.5	111	42.5	37.5	4	5	155.1	143	20.3	14.36
145	7	41	45.5	48.5	114	40	43	4	3.5	136	151.5	20.3	13.38
146	9	58	61	65	113	45	46.5	6	2.5	144.5	124	124	9.68
147	7.5	60.5	84.5	69.5	114	40	41.5	4	5.5	200.5	156.5	14.9	10.85
148	10	30.5	35	37.5	110	30.5	25	2	2	48	49	108	22.11
149	9.5	70	78	78.5	114.5	43	33	4	5.5	119	129	15.65	13.86
150	8.5	36.5	33	37.5	107	35.5	36.5	2.5	2	89.5	88.5	20.3	23.43
151	9	30	34	37	113.5	31	26.5	2.5	2.5	8.2	86.5	18.25	18.25
152	8.5	34	41	41	108.5	35.5	33	25	2.5	87.5	87	164	19.01
153	8	38	41	44	108	38.5	30.5	2	1.5	94.5	101.5	23.8	23.31
155	8.5	52.3	59.5	59.5	110	41.5	43	4.5	6.5	120.5	100	21.3	21.34
156	7	44.5	50.5	52	111.5	40.5	39	3.5	3	62	59.5	13.36	22.41

APPENDIX 5

Weather report during the crop growth period

Year	Std Week	Rain (mm)	Evap (mm)	Max Temp (oC)	Min Temp (oC)	Rel Humidity1 at 07 17 (%)	Rel Humidity2 at 14 17 (%)	Wind Velocity (Kmph)	Solar Radiation (mj/ m2)	Bright Sunshine (Hrs)
2000	42	16 19	29 5	31 05	19 65	89 57	50 14	3 97	15 12	5 85
2000	43	0	36 2	32 81	17 51	88	35 71	2 75	18 57	9 59
2000	44	0	30 69	30 6	17 31	90 71	38 57	3 78	15 65	8 21
2000	45	0	36 29	30 75	16 32	90 57	37 85	3 97	16 6	9 38
2000	46	0	36 8	29 67	13 92	90 28	36 14	4 91	17 55	9 9
2000	47	0	32 5	30 21	14 24	90 57	34 42	4 21	15 94	8 84
2000	48	3 09	32 6	29 38	16 25	85 14	39 71	3 72	13 19	6 89
2000	49	0	36 89	29 18	10 39	80 42	25 14	3 84	16 67	9 19
2000	50	0	36 6	29 39	9 65	85 28	20 42	3 98	17 41	10 35
2000	51	0	38 79	28 85	9 11	89 57	23 28	4 09	17 02	10 0"
2000	52	0	41 39	28 52	10 57	89 12	27 87	5 55	16 43	10 01
2001	1	20	22	26 45	14 72	92	54 85	5 08	11 81	6 31
2001	2	0	34 39	29 75	14 95	90 14	32 14	6 6	16 32	9 5
2001	3	0	37 6	29 95	14 61	92 71	35 71	7 52	15 54	8 7
2001	4	0	37 89	29 51	10 48	83 14	21 71	4 54	17 42	9 24
2001	5	0	40 5	31 61	11 68	86 14	19 42	5 18	17 11	9 37
2001	6	0	50 1	32 97	12 47	73	19 14	4 97	18 94	10 51
2001	7	0	49 19	33 02	15 07	81	19 57	6 75	19 48	10 32
2001	8	0	56 2	34 54	15 05	68 28	17 57	4 97	20 05	10 35
2001	9	0	64 9	34 89	16 58	77 71	20 42	9 95	21 15	10 28