GENETICS OF TRAILING HABIT IN YARD LONG BEAN
(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)

By

ANISHA GEORGE

THESIS

submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture
(PLANT BREEDING AND GENETICS)

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2004

DECLARATION

I, Anisha George (2002-11-12) hereby declare that this thesis entitled **'Genetics of trailing habit in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)'** is a bonafied record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara
Date: 4/12/2004

Anisha

ANISHA GEORGE

CERTIFICATE

Certified that this thesis, entitled **'Genetics of trailing habit in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)'** is a record of research work done independently by **Ms. Anisha George** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Maureen Abraham

Dr. Mareen Abraham
Chairman, Advisory Committee
Assistant Professor
Department of Plant Breeding and Genetics
Cashew Research Station
Madakkathara
Kerala Agricultural University
Thrissur, Kerala

Vellanikkara
Date: 4/12/2004

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms. Anisha George**, a candidate for the degree of **Master of Science in Agriculture**, agree that this thesis entitled **'Genetics of trailing habit in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)'** may be submitted by **Ms. Anisha George,** in partial fulfillment of the requirement for the degree.

4/12/04
Dr. Mareen Abraham
Chairman, Advisory Committee
Assistant Professor
Department of Plant Breeding and Genetics
Cashew Research Station
Madakkathara

4/12/04
Dr. Achamma Oomen
(Member, Advisory Committee)
Professor and Head
Dept.of Plant Breeding and Genetics
College of Horticulture
Vellanikkara

4/12/04
Dr. T.R. Gopalakrishnan
(Member, Advisory Committee)
Associate Professor and Head
Department of Olericulture
College of Horticulture
Vellanikkara

4/12/04
Dr. V.V. Radhakrishnan
(Member, Advisory Committee)
Associate Professor & P.I.
AINP on Medicinal & Aromatic Plants
Dept. of Plant Breeding and Genetics
College of Horticulture
Vellanikkara

4/12/04
(EXTERNAL EXAMINER)

ACKOWLEDGEMENT

First and foremost, I humbly bow my head before the Almighty for the unmerited blessings through various hands. I submit this small venture before God with full satisfaction and pleasure from my heart.

I avail this opportunity to express my deep sense of gratitude and respect to my chairman ***Dr. Mareen Abraham****, Assistant Professor, Department of Plant Breeding and Genetics, for her revered guidance, critical suggestions, constant encouragement, generous support which made smooth progress of my research project.*

I am respectfully thankful to ***Dr. Achamma Oomen****, Professor and Head, Department of Plant Breeding and Genetics, and member of my Advisory Committee for her valuable suggestions, critical scrutiny of the manuscript and ever willing help during the course of research.*

With deep respect, I express my wholehearted gratefulness to ***Dr. V. V Radhakrishnan****, Associate Professor, Department of Plant Breeding and Genetics, and member of my Advisory Committee for his never ending encouragement, keen interest, valuable suggestions, constructive criticisms and timely help throughout the course of this investigation.*

It is my pleasant privilege to acknowledge ***Dr. T.R. Gopalakrishnan,*** *Associate Professor and Head, Department of Olericulture and member of my advisory committee for his precious advices, ever willing help, critical analysis of the manuscript and the help rendered for the conduct of the field work.*

I am especially obliged to my teachers of the Department of Plant Breeding and Genetics Dr. C.R. Elsy (Assistant Professor), Dr. K. Nandini (Associate Professor), Dr. K. Arya (Assistant Professor), Dr. Dijee Bastian (Assistant Professor), Dr. T. Girija (Assistant Professor) and Dr. K.T. Prasannakumari

(Associate Professor) for their kind concern, sincere advices, help and support rendered during this investigation and throughout my study period.

I express my sincere thanks to all the nonteaching staff of Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara.

I acknowledge each and every one of the labourers of the College of Horticulture for assisting me to make this venture fruitful.

I accord my sincere thanks to Sri Santhosh for the timely help during computer work.

The award of KAU Junior Research Fellowship is gratefully acknowledged.

With all my regards, I deeply cherish the timely help, and support provided by my senior and junior friends. More personally, I would like to thank my senior Smt. Ambili for her sincere help and interest extended for the statistical analysis.

True words of thanks to all my batch mates, personally I am grateful to my close friends Smitha, Priya, Binimol, Preetha, Anuja, Renitha and Shahida who were with me through thick and thin with constant encouragement and help.

Words fall short in expressing my heartfelt thanks to my dear classmates, Chandrashekhar and Divya who provided the much needed shoulders with immense patience and understanding. I am really lucky to have their wholehearted cooperation and encouragement.

I am forever indebted to my parents ***Sri M.A. George*** *and* ***Smt. Metilda*** *whose mellifluous love, prayers, personal sacrifices and constant support were my morale booster for completing this work. Words cannot express my soulful gratitude to my beloved brother* ***Axin*** *for his love, care and support. With deep sense of respect and affection, I dedicate this beautiful petal of my life as a token of eternal love.*

Anisha George

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

Crop improvement started with the primitive man changing his mode of life from a nomad to an agriculturist. Genetic improvement for higher production and better quality of crop plants has been an important objective in scientific research. Hybridization offers far greater possibilities in crop improvement than any other conventional breeding methods. It is the only effective means of combining the desirable characters of two or more varieties. Breeding for improved vegetable varieties is an important area where breeders have more scope for genetic improvement. The varietal requirements in terms of plant type, seed type, pod colour, maturity and use pattern are extremely diverse from region to region making breeding programmes in cowpea more complex than any other crop. Evolving vegetable and seed type cowpea cultivars having an erect plant type with determinate plant growth and long, tender and string less pods is one of the objectives in cowpea breeding. Among the leguminous vegetables, genetic improvement programme in cowpea forms a major part of research programme at both national and international level.

Cowpea *(Vigna unguiculata* (L.) Walp.) also called as southern cowpea and black-eyed cowpea, is well adapted to the tropics. All evidences indicate that cowpea is originated in Africa. Its quick growth and rapid ground coverage have made cowpea an essential component of sustainable agriculture in marginal lands and other regions of the tropics (Singh *et al.*, 1997). Among the cultivated ones, four groups have been identified:(1) *unguiculata* grain type, which is the major group; (2) *biflora* or *catjang,* which is differentiated mainly by its small erect pods (3) *sesquipedalis*, the yard long bean, which has very long pods and trailing growth habit and (4) *textiles,* which is an old primitive cultivar grown for the textile fibers obtained from its long peduncles (Baudoin and Maiechal, 1985).

V. unguiculata var. *sesquipedalis* is known as yard long bean or asparagus bean. It's pods and leaves are used as vegetable. Plants are trailing or climbing. Pods are pendent, 30-90 cm long, fleshy and inflated, tending to shrink when dry. Seeds are elongated, kidney shaped, 8-12 mm long. Such cultivars are found in India, Indonesia, Philippines and Srilanka (Sharma and Joshi, 1993). Yard long bean has excellent nutrient compositions. Under field conditions, specific content of protein is 28.3 per cent (% dry weight) and carbohydrate is 66.1 per cent. Hence it is a right replacement for animal protein as well as other beans likes french beans that are commercially costlier.

In India, cowpea is known since Vedic times. West Africa and India are centers of diversity for this crop. It is a multi season and multipurpose crop, which can fit in to a variety of mixed farming system and hence vegetable cowpea is extensively cultivated in Kerala and Karnataka. The trailing habit of vegetable cowpea increases the cost of cultivation as it needs stacking or *pandal* for its growth .In Kerala, most preferred types are the yard long cowpea with fleshy tender pods. Due to the succulent and soft bodied nature of pods, yard long bean varieties are susceptible to pests and diseases particularly mosaic and *Colletotrichum* diseases in farmers fields. The bush varieties have lesser incidences of these diseases compared to trailing types.

The quantitative and qualitative characters can be improved only through systematic breeding programmes. The growers in Kerala have stressed the need for a short duration bushy variety of cowpea with pod characters of trailing and plant type of bush varieties. Hence a combination breeding programme was formulated involving diverse parents, viz. two yard long bean types *(Vigna unguiculata* sp. *sesquipedalis)* and three bush type cowpea *(Vigna unguiculata* ssp. *unguiculata)*, which will give an insight into the genetics of trailing nature and its inheritance pattern. The present study was undertaken with the following objectives:

1. To study the gene action of trailing trait in yard long bean
2. To combine the desirable pod characters of trailing and plant type of bush varieties
3. To identify ideal plant type having the pod characters of trailing type and plant type of non-trailing type

Review of Literature

2. REVIEW OF LITERATURE

A brief review of the literature on various aspects of crop improvement with special reference to trailing habit in cowpea and related crops is presented under the following heads.

2.1 Combining ability and gene action

2.2 Inheritance studies

2.3 Studies on variability

2.4 Heritability and genetic advance

2.5 Correlation studies

2.6 Path coefficient analysis

2.7 Heterosis

2.1 COMBINING ABILITY AND GENE ACTION

Combining ability analysis helps in the evaluation of inbred in terms of their genetic value and in the selection of suitable parents for hybridization. General combining ability (*gca*) is due to additive effect of genes, where as *specific combining ability (sca) is due to dominance deviation* and epistatic interaction (Sprague and Tatum, 1942). Further, it serves as a powerful tool to elucidate the nature and magnitude of various types of gene action involved in the expression of quantitative traits (Dhillion, 1975).

2.1.1 Plant height

Rejatha (1992) reported that the variance due to *gca* was significant and higher in magnitude than *sca* for internode length. According to Thiagarajan *et al.* (1993) the variance due to *gca* and *sca* showed that gene action was predominantly non-additive for plant height. Madhusudan *et al.* (1995) reported the importance of non-additive gene action for plant height in a line x tester analysis involving nine lines and three testers. Jayarani and Manju (1996) noticed the importance of non-additive gene action for plant height in a combining ability analysis involving two lines, six testers and twelve hybrids.

Combining ability was studied in a 10x10 diallel cross in cowpea by Sobha *et al.* (1998) and reported that the variance due to general combining ability and specific combining ability showed both additive and non-additive gene action for plant height. Sharma (1999) reported that plant height showed high genetic advance coupled with high heritability and GCV indicating a preponderance of additive gene effects for this trait. Borah *et al.* (2000) observed that highly heritable character like plant height is under the influence of additive gene action. Satish kumar (2000) reported that non-additive gene action had a major role in plant height.

2.1.2 Other yield components

Amma (1981) noticed that plant height, commencement, completion and spread of flowering, length and weight of individual pods and number of seeds per pod were inherited as quantitative characters controlled by either polygenes or by a few major genes whose action is suitably modified by minor genes. Jalajakumari (1981) observed the role of additive genes for characters like number of pods per plant, length and weight of individual pods, and pod yield per plant. Combining ability studies are carried out by Tiwari (1993) through a 5x5 diallel cross in mung bean and found that additive gene effects were predominant for number of branches per plant and non-additive effects were predominant for days to maturity and plant height. Kapila *et al.* (1994) while studying the combining ability analysis involving ten lines and two testers over two locations for nine traits in soybean revealed that both additive and non-additive genetic variance were important for number of pods per plant.

Patel *et al.* (1994) reported the significant mean squares due to *gca* as well as *sca* for all the yield components in cowpea. The highest magnitude of GCA variance compared to SCA variance signified the predominant role of additive type of gene action in the expression of all the characters. Combining ability analysis was done by Shanmugasundaram and Rangasamy (1994) using $20F_1$ and $20F_2$

families obtained from a 5 x 5 diallel mating design for yield and its components. Highly significant GCA, SCA and reciprocal variances were observed for number of seeds per pod in both F_1 and F_2 generations. Sobha (1994) observed that when parents possessing high general combining ability were crossed, the F_1 hybrids gave better performance and additive and non-additive gene effects in the inheritance of majority of the characters Smitha (1995) reported the involvement of *sca* alone for the inheritance of seed yield per plant and number of seeds per pod. A preponderance of *sca* effects was observed for number of pods per plant.

The GCA: SCA variance ratio for all the yield related traits in cowpea showed the predominance of SCA variance over GCA variance, suggesting the predominance of non-additive gene action (Aravindhan and Das, 1996). The ratio of *gca* to *sca* for all the yield related traits in cowpea showed non-additive gene effects except days to 50 per cent flowering (Bhushana *et al.*, 1998). Triple test cross analysis in two crosses of vegetable cowpea was carried out by Nagaraj *et al.* (2002) and reported that days to 50 per cent flowering and days to first picking exhibited significant additive gene action, where as pod length showed dominant gene action.

2.2 INHERITANCE STUDIES

Relevant literatures regarding the inheritance of genes controlling different characters have been reviewed here under.

2.2.1 Growth habit

Premsekar and Raman (1972) observed monogenic inheritance for growth habit (bushy/trailing) in progenies of hybrid between *V. sinensis* (L.) savi and *V. sesquipedalis* (L) Frun. Frey (1985) has compiled an exhaustive list of 159 genes and he reported that *'df'* gene is responsible for dwarf character with short internodes and *'Sh'* gene is responsible for spindly growth habit with marked elongation of main stem. Karkanavar *et al.* (1991) obtained a trigenic ratio of 39 tendriller: 25 non-tendriller plants in F_2 generation with one basic, one inhibitory and one anti-inhibitory gene in cowpea. Uguru and Uzo (1991) studied the data from different crosses of cowpea accessions with different growth forms. From F_1 and F_2 data, they indicated that two allelic pairs, *AA* and *BB* are responsible for the inheritance of growth habit. They also reported that the gene interaction in which the genotype *AB* had the decumbent growth habit, *aaB* had the climbing and *aabb* had the bushy habit.

Study was conducted by Talukdar and Talukdar (2003) on the inheritance of growth habit and leaf shape in mungbean and concluded that all the F_1 plants, indeterminate in growth habit, have complete dominance of indeterminate over determinate and in F_2 the segregation ratio was 3:1. In superior cross combinations involving bush cowpea and yard long bean, a perfect monohybrid ratio of 3:1 for bushy and trailing types was observed in four crosses by Valarmathi (2003). She also reported that this character was governed by single gene, which had one allele that was completely dominant and other a recessive allele, indicating complete dominance for this trait.

2.2.2 Flower colour, Stem colour, Seed colour, Pod colour

Premsekar and Raman (1972) reported a monogenic segregation pattern for dark purple and white standard petal in across involving *V. sinensis* (L.) savi and *V. sesquipedalis* (L) Frun. Karkannavar *et al.* (1991) reported a complementary digenic ratio of 9:7 for stem pigmentation (purple:green) in cowpea. Joshi *et al.* (1994) carried out segregation analysis for calyx, corolla and pod tip colour in F_1 and F_2 progeny of a cross between Virginia and Iran gray and indicated the presence of a basic pleiotropic gene *(PI)* responsible for the expression of pigmentation on these plant parts together with localizing genes conditioning colouration on specific plant parts.

Modified dihybrid ratio of 9:3:4 in seven crosses was reported by Neema (1996) for seed coat colour pattern suggesting supplementary gene action. Inheritance study of calyx, standard petal pigmentation and flower colour in cowpea revealed that violet flower colour was dominant over light violet and was controlled by two complementary genes (Venugopal and Goud, 1996).

Bhuvaneswari (2001) reported 3:1 (purple:green) monohybrid ratio for pod pigmentation and stem pigmentation in lablab. For stem pigmentation, dihybrid ratio of 9:7 (purple:green) and for flower colour, a monohybrid ratio of 3:1 (purple:white) was obtained in the F_2 segregating generation for different combinations (Valarmathi, 2003).

2.3 STUDIES ON VARIABILITY

The variability available in the segregating material is important for selection programme in any crop. Variability in a population is measured by phenotypic and genotypic coefficient of variability. The relevant literature pertaining to the variability studies with respect to cowpea is documented below.

In cowpea, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were similar for pod yield and its five components. Pods per plant, pod length and pod yield per plant exhibited high genotypic and phenotypic variation (Chattopadhay *et al.*, 1997). Feng *et al.* (1997) studied ten important agronomic characters of 1192 accessions of yard long bean and observed very high variability for characters like pod length, pod weight, pod shape, pod colour and seed coat colour. Vardhan and Savithramma (1998) observed high GCV and PCV for plant height, number of primary branches, number of secondary branches, pods per plant and plant height in cowpea. High genotypic coefficient of variation and phenotypic coefficient of variation were observed for plant height, number of pods per plant, seed yield per plant and number of branches per plant (Anbuselvam *et al.*, 2000).

Kalaiyarasi and Palanisamy (2000) observed that seed yield per plant and number of pods per plant had high estimates of GCV followed by 100 seed weight, number of seeds per pod and plant height in F_4 population of cowpea. Pournami (2000) conducted variability studies with 15 vegetable cowpea genotypes and observed maximum GCV for number of pods per plant. Jyothi (2001) in a Line x Tester analysis using seven parental lines reported that number of flowers per plant, pod yield per plant and number of pods per plant exhibited higher values of GCV. Fifty varieties of yard long bean were evaluated for yield and related characters by Vidya *et al.* (2002) reported high phenotypic and genotypic coefficient of variation for number of pods per plant and pod weight.

2.4 HERITABILITY AND GENETIC ADVANCE

The degree to which the variability of a quantitative trait may be transmitted to the progeny is referred to as heritability. The genetic advance would be high, if the heritability was due to additive gene action. The heriatability estimates recorded and reported by various workers for different characters are reviewed below.

Genetics of pod yield and its components were studied in F_2 and backcross populations of a cross-involving two vegetable cowpea varieties by Pathmanathan *et al.* (1997). He recorded the broad sense heritability for pod weight was 84 per cent and the narrow sense heritability was 75 per cent indicating good genetic variability for effective selection. Rajaravindran and Das (1997) studied variability in five yield related traits in seven vegetable cowpea genotypes and reported highest heritability for pod length followed by days for 50 per cent flowering. Number of pods per plant recorded lowest heritability. Genetic advance was high for number of pods per plant. High heritability estimates were recorded for pod and peduncle length, seeds per pod, plant height and branches per plant in a variability study with 34 cowpea genotypes by Ram and Singh (1997). High heritability combined with high genetic advance was observed for pod length.

Resmi (1998) studied 30 different genotypes of yard long bean and observed significant differences among the genotypes for all the 24 characters studied. Heritability was highest for pod weight and pod length. High heritability along with high genetic advance was reported for pod yield per plant and pod weight. Sharma (1999) studied genetic variability for eight yield related traits among 42 diverse genotypes of cowpea and high heritability was observed for many characters. Plant height showed high heritability coupled with high genetic advance. Heritability and genetic advance were assessed for 50 genotypes of cowpea by Anbuselvum *et al.* (2000) and high estimates of heritability were observed for plant height, length of the pod and days to 50 per cent flowering.

The genetic variability study was carried out with 24 genotypes of cowpea by Tyagi *et al.* (2000). They suggested that high values of heritablity, GCV and genetic advance for days to 50per cent flowering, plant height, and seed yield per plant will lead to effective selection based on these characters. Vidya *et al.* (2002b) reported high heritability estimates in conjunction with high genetic advance were observed for number of pods per plant, pod weight and pod length. Valarmathi (2003) observed wide range of variation among F_2 families for single pod weight and pod length. Yield and yield components exhibited high heritability estimates except for the traits like branches per plant and pods per cluster, which exhibited low to moderate heritability.

2.5 CORRELATION STUDIES

Correlation analysis measures the mutual relationship between various plant characters and gives reasonable indication for plant breeders on selection of various characters.

Seed yield exhibited a significant and positive correlation with clusters, flowers and pods per plant, plant height, pod length and seeds per pod (Parihar *et al.*, 1997). According to Singh *et al.* (1998) genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficients for morphological traits in cowpea. Grain yield per plant was positively and significantly associated with clusters per plant, pods per plant and biomass per plant. Correlation analysis was carried out by Rangaiah and Mahadevu (1999) in cowpea and reported that number of pods per plant, pod length and number of seeds per pod were positively correlated to seed yield. Vidya (2000) reported that genotypic correlation of pod yield per plant was highly significant and positive for number of pods per plant, number of pods per inflorescence, pod weight and pod length. Number of primary branches also recorded positive correlation with yield.

Bastian *et al.* (2001) recorded that plant height, number of branches per plant, number of pods per plant, pod length and number of seeds per pod were positively correlated to seed yield. Correlation conducted on 37 divergent genotypes of vegetable cowpea by Kutty *et al.* (2003) and study revealed that number of pods per plant, number of pickings, average weight of pods and pod length were positively and significantly correlated with yield per plant both at phenotypic and genotypic levels. Studies on correlation and path analysis were carried out in the F_2 generation of the five crosses of cowpea by Malarvizhi and Rangasamy (2003) and reported that seed yield was positively correlated with its component traits in the order of number of primary branches, number of clusters per plant and number of seeds per pod.

Correlation analysis was carried out using 20 diversified genotypes of cowpea for 12 component characters of yield by Venkatesan *et al.* (2003) and reported that branches per plant, clusters per plant, pods per cluster, pods per plant and pod yield had positive correlation with seed yield both at genotypic and phenotypic level.

2.6 PATH COEFFICIENT ANALYSIS

Certain characters might indirectly influence yield but their correlation with yield may not be statistically significant. In such cases, path coefficient analysis is an efficient technique, which permits the separation of correlation coefficients into components of direct and indirect effects.

Path coefficient analysis of green pod yield in cowpea by Chattopadhyay *et al.* (1997) indicated green pod weight, dry pod weight, pod number and seeds per pod as the most important components of pod yield because of their high positive direct effects. Days to flowering registered high negative direct effect indicating early flowering contributes to yield. Resmi (1998) reported that number of pods per plant exerted the maximum positive direct effect on pod yield followed by pod weight in vegetable cowpea. Pod length exerted positive indirect effect on pod yield through pod weight and number of pods per kg while pod weight exerted indirect effect through number of pods per kg. Path coefficient analysis for green pod yield in cowpea by Vardhan and Savithramma (1998) indicated that green pods per plant, pod length, number of primary branches were the major traits contributing to yield.

Pournami (2000) reported that days to first flowering exerted the maximum direct effect on pod yield followed by number of pods per plant. Days to first harvest, length of harvesting period and number of inflorescences per plant exerted negative direct effect on pod yield. Path analysis revealed that number of branches per plant and pod weight as the main yield contributing characters (Ajith, 2001). Path coefficient analysis indicated the maximum direct effect on yield by number of pods per plant followed by pod weight and number of pods per inflorescence. Number of pods per plant also exerted positive indirect effect through length of harvesting period and number of pods per inflorescence (Vidya and Oomen, 2002a).

The path analysis conducted on 37 divergent genotypes of vegetable cowpea revealed that number of pods per plant followed by average weight of pods and number of pickings have maximum positive direct effects on yield. The direct effects of pod length and days to first picking were low mainly due to high indirect effects via average weight of pods and pods per plant (Kutty *et al.*, 2003). Subbiah *et al.* (2003) reported that number of branches per plant, pod weight, seeds per pod and pod length had positive direct effect on yield. Venkatesan *et al.* (2003) carried out path analysis using 20 diversified genotypes of cowpea and reported that number of pods per plant, pod length, seeds per pod and seed weight had positive and direct effect on seed yield.

2.7 HETEROSIS

The presence of heterosis indicates the ability of the parents to combine well in a hybridization programme. For varietal breeding programme, more knowledge of the extent of heterosis is of no use and so it is necessary to understand the cause of heterosis in F_1. Higher expression of F_1 may be due to fixable (additive) type of gene action and or non-additive type of gene action. Thus combining ability helps in identifying desirable cross combinations. Inasi (1980) observed heterosis in hybrids of both genetically related and unrelated parents.

2.7.1 Plant height

Mylswamy (1988) studied 84 F_1s obtained in a LxT design and reported significant positive heterosis over the mid parent in 47 F_1s. Highest heterosis of 52.92 per cent in a cross Rc x CO 4 was reported by him for this character. Hazra *et al.* (1993) reported significant positive heterosis for seven F_1s out of 10 F_1s studied. The range was from 12.3 to 57.8 per cent over the mid parent and he reported positive and significant heterobeltiosis for three F_1s ranging from 25.2 to 42.5 per cent. Selvalakshmi (1995) reported that seven out of 21 hybrid combinations showed significant positive heterosis over mid parent ranged from 6.81 per cent to 32.96 per cent. Heterosis over better parent ranged from 41.81 per cent to 19.60 per cent. Shashibushan and Chaudari (2000) reported a range of –47.7 per cent to 42.3 per cent standard heterosis and –22.9 per cent to 23.9 per cent relative heterosis.

2.7.2 Other yield components

Bhaskariah *et al.* (1980) reported that the relative heterosis was in the range of –20.1 to 36.1 and heterobeltiosis from –32.6 to 19.5 per cent for number of seeds per pod. Singh (1983) observed significant positive heterosis for number of seeds per pod in nine crosses out of fifty crosses. The hybrid GC 170 x PS 42 recorded the highest heterosis of 32.14 and 29.28 per cent over both the parents respectively. Singh *et al.* (1986) demonstrated negative relative heterosis of –12.65 and standard heterosis of –11.63 for days to 50 per cent flowering. Mylswamy (1988) found that five crosses out of 84 crosses exhibited significant positive heterosis over the mid parent for number of branches per plant. The hybrid V16x KM 1 recorded the highest heterosis of 28.57 per cent over the mid parent.

Lodhi *et al.* (1990) observed a range of –10.16 to 7.25 relative heterosis and –10.16 to 10.27 standard heterosis for days to 50 per cent flowering. Hazra *et al.* (1993) reported heterosis in the range of –21.0 to 28.5 over their mid parent and –6.3 to 11.2 over their better parent for pod length. The highest relative heterosis and heterobeltiosis was observed in the cross *Assam local 1* x Dumca local 1, which were 28.5 and 11.2 per cent respectively. A maximum of 20.4 per cent of heterobeltiosis was reported by Sangwan *et al.* (1995) for number of seeds per pod. Selvalakshmi (1995) reported heterosis for number of seeds per pod in the range of –23.78 to 19.04 per cent. Two-hrbrid viz., CO 2 x CO 1 and CO 2-1 x Kerala selection exhibited significant positive relative heterosis. For most of the hybrids, the heterobeltiosis was significant but negative.

Rajkumar *et al.* (1999) reported a range of –24.43 to 9.84 per cent heterobeltiosis for number of seeds per pod. In a study of L x T analysis, Bhushana *et al.* (2000) reported the lowest positive heterosis over mid parent (30.31%) for pod length. Shashibushan and Chaudari (2000) indicated a range of (-16.3 to 26.8%) relative heterosis and –35.2 to 23.4 per cent standard heterosis for pod length.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was carried out at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period 2002-2004. The field experiments were conducted in the research fields of Department of Olericulture which is located at latitude of 10^0.3'N, longitude of 76^0 30'E and at an elevation of 22.2M above MSL. The area enjoys a warm humid tropical climate. The soil type is laterite loam with p^H around 5.6.

3.1 MATERIALS

Five cowpea varieties, of which two are trailing varieties namely Lola (white and long poded) and Vyjayanthi (purple and long poded) and three non trailing varieties, namely Pusa Komal, Bhagyalakshmi and TC-99-1 were used for the above investigation.

3.2 METHODS

3.2.1 Experiment 1

Five cowpea varieties (two trailing varieties namely Lola (white and long poded) and Vyjayanthi (purple and long poded) and three non trailing varieties namely Pusa Komal, Bhagyalakshmi and TC-99-1 were raised in a randomized block design with five replications. Details of parents used in the study are given in Table 3.1. Single row of seeds were sown 45 cm apart on ridges of 3.5 m length taken at a spacing of 1.5 m. Biometrical observations were taken for parents-two trailing and three non-trailing. Varieties were hybridized in a 5x5 diallel cross during *Kharif* 2003.

Table 3.1 Details of parents used in the study

Sl.No	Parents	Source
1	Lola	KAU, Thrissur
2	Vyjayanthi	KAU, Thrissur
3	Bhagyalakshmi	KAU, Thrissur
4	Pusa Komal	RARS, Pattambi
5	TC-99-1	RARS, Pattambi

3.2.1.1 Planting

Paired parent arrangement was used, which facilitated proper mating. Staggered planting of parents was carried out to ensure the availability of pollen and female flowers for hybridization.

3.2.1.2 Hybridisation technique

The anthesis time for cowpea is between 7 to 9 am. However, the flowers open late in the morning, the dehiscence of the anthers is much earlier. Emasculation was carried out in mature flower buds in the preceding evening. The emasculation method that is generally practiced for cowpea was followed initially, which is as follows. The bud is held between the thumb and the forefinger with the keel petal uppermost. A needle was run along the ridge where the two edges of the standard unite. One side of the standard was brought down and secured position with the thumb. Same thing was done with one of the wings. After this the exposed keel was slit on the exposed side. A section of keel was also brought down and secured in position under the end of thumb. Ten stamens were removed with pointed forceps and pollen from male parent was applied. The disturbed parts of standard, wing and keel were brought in original position as far as possible. A butter paper cover was used to cover and protect the bud. With the above method the mechanical injury caused during emasculation was high and the pod set was only 40-50%. So a new method was adopted for hybridization.

The method used is as follows. In the preceding evening of hybridization, the mature flower buds are selected. The bud is held between the thumb and the forefinger with the standard petal uppermost. A small incision at half-length of the standard petal is given on the top portion of the bud from the pedicelar distal end. With the help of forceps, half portion of flower bud is removed carefully, leaving stigma and stamens. Then stamens are removed and the emasculated flower is tagged. Bud is protected with butter paper cover, which also avoid accidental pollination with foreign pollens. Next day morning, butter paper cover is removed and pollination is done with required male parent. After pollination, butter paper cover is kept for two days and removed after pod set. Using this method, a pod set of 80-85% obtained. Therefore, this method is standardized, and practiced for good pod set. Tagging is done. Pod is set within three days. Crossed seeds are used for raising F_1 population. Path analysis and correlation studies are carried out for parental population.

3.2.2 Experiment 2

In Experiment 2, twenty five genotypes (20 hybrids and five parents) were raised in RBD with two replications during January to April 2004. Single row of ten seeds were sown 45 cm apart on ridges of 3.5 m length taken at a spacing of 2m. Observations on various biometrical traits were recorded. The data was analysed for estimating GCA variances and its effects, SCA variances and its effects, *gca-sca* ratio etc.

3.2.3 Experiment 3

The F_2 population was raised from the seeds obtained from Experiment 2. Fifteen plants were selected for each cross from three replications. Segregation of characters was studied from the above population. Statistical analysis of the data was done for ANOVA and χ^2 test was done for segregation ratio of characters.

Crop for all the three experiments was raised following package of practices of Kerala Agricultural University (KAU, 2002)

3.3 OBSERVATIONS RECORDED

Five plants were randomly selected from each replication. Observations were recorded on the following characters and the average worked out.

i. Length of main vine at final harvest (cm)

Length of the main vine was measured at the time of final harvest of the plant. Height was measured in cm from the ground level to the tip of the plant.

ii. Stem thickness (mm)

Stem thickness was measured from the basal portion of the plant five cm away from the collar region at the time of harvest and recorded in mm.

iii. Number of branches per plant

Number of primary branches per plant was studied at the time of final harvest. The branches per plant were counted separately and the average was calculated and recorded.

iv. Days for first flowering

The number of days from sowing to the appearance of the first flower was recorded.

v. Days to first harvest

The days taken from sowing to the first harvesting for matured pods in each plant was recorded.

vi. Number of pods per plant

Pods harvested periodically from each plant were separately counted, average worked out to obtain the total number of pods per plant.

vii. Number of seeds per pod

The number of seeds in the randomly selected pods was counted and average number of seeds per pod was worked out.

viii. Average weight of pod (g)

The weight of the above selected pods was taken using an electric balance and the average worked out in g.

ix. Length of the pod (cm)

Length of the randomly selected pods from each observational plant was measured using an ordinary scale and recorded in cm.

x. Number of harvests

Number of harvests for each observational plant was counted and recorded.

xi. Duration of crop

The days taken from sowing to the last harvest for matured pods in each plant was recorded.

xii. Pod yield

Weight of pods from observational plants at each harvest was taken using a top loading balance and the average recorded in g.

Observations on plant habit, pod colour, flower colour, stem colour and seed colour were taken from each observational plant and recorded. Incidence of major pests like birds and diseases like pod rot was also noted.

3.4 STATISTICAL ANALYSIS

The data collected from the present study were analysed by using various biometrical techniques. The analysis was carried out using SPAR1 software package.

3.4.1 Estimation of genetic parameters

The following genetic parameters were worked for the Experiment 2

3.4.1.1 Phenotypic and genotypic coefficient of variation

The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated. The PCV and GCV values were classified as suggested by Sivasubramaniam and Menon (1973) that,

0 to 10 per cent	- Low
10 to 20 per cent	- Medium
20 per cent and above	- High

3.4.1.2 Heritability

Heritability in broad sense was estimated using the formula of Hanson *et al.* (1956). The heritability was classified as suggested by Robinson *et al.* (1951).

0 to 30 per cent	- Low
30 to 60 per cent	- Moderate
60 per cent and above	- High

3.4.1.3 Genetic advance

Genetic advance was worked out as per the formula suggested by Johnson *et al.* (1955) and genetic advance as percentage of mean was calculated as per the formula given below.

$$\text{Genetic advance as per cent of mean} = \frac{\text{Genetic advance}}{\text{Grand mean}}$$

3.4.2 Correlation studies, Path coefficient analysis

The data collected from Experiment 2 was subjected to correlation studies and path coefficient analysis. The characters that showed significant genotypic correlation with pod yield per plant were subjected to path analysis as per Dewey and Lu (1959).

3.4.3 Diallel analysis

The observations on combining ability of parents and hybrids of diallel recorded from Experiment 2 was analysed using the numerical approach of Griffing (1956) in Method 2 and Model 1.

3.4.4 Heterosis and Inbreeding depression

Heterosis is estimated in three different ways.

Heterobeltiosis : $[(F_1\text{-}BP)/BP] \times 100$

BP- mean value of the better parent

Mid-parent Heterosis : $[(F_1\text{-}MP)/MP] \times 100$

MP- mid parental value

Standard Heterosis : $[(F_1\text{-}SP)/SP] \times 100$

SP- mean value of the standard parent]

Inbreeding depression = $[(F_1\text{-}F_2)/F_1] \times 100$

3.4.5 ANOVA and χ^2 test

The data from Experiment 3 was subjected to ANOVA and χ^2 test to study the segregation of characters.

Results

4. RESULTS

4.1 EXPERIMENT 1

4.1.1 Genetic variability

In any breeding programme, to induce genetic variability through hybridization and selection, prime importance has to be given for choice of parents. Genetic variability among the parents for the desired traits is the first criteria to be taken to consideration for selecting the parents for hybridization. With this view in mind, the five parents used for hybridization in this study were laid out in RBD with five replications during *Kharif* 2003 (Plate 1.). The mean performances of these genotypes for quantitative and qualitative characters are presented in Table 4.1. The data obtained for the 12 quantitative traits from the five parents were statistically analysed. The ANOVA for different traits of yield and yield components of the parents were presented in Table 4.2. All the traits studied have shown significant differences among the parents.

4.1.1.1 Mean, Range, Coefficient of Variation

For assessing the magnitude of any breeding material, the parameters of mean, range and coefficient of variation for different traits have to be assessed. The above parameters have been estimated for all the yield components and presented in Table 4.3. Maximum vine length at final harvest was noticed for Vyjayanthi (434.56 cm) and minimum vine length for Bhagyalakshmi (48.4 cm). Mean value for length of main vine at final harvest was 183.2 cm. Vyjayanthi had maximum number of branches (12.64) where as TC-99-1 had minimum number of branches per plant (6.48). Mean value for this character was 9.74 cm. Days to first flowering were highest for Lola (60.48) and lowest for Bhagyalakshmi (39.9) and Mean value observed for days to first flowering was 48.45. Days to first harvesting ranged from 54.9 (TC-99-1) to 79.04 (Lola) with a mean of 64.5. Length of the pod was maximum for Lola (50.56 cm) and minimum for TC-99-1 (17.16 cm) and the mean value was 32.5. Number of pods per plant ranged from 8.88 (TC-99-1) to

Plate 1. Field view of parental lines

Table 4.1 Mean performance of five genotypes of cowpea for 17 characters

Characters	Lola P_1	Vyjayanthi P_2	Bhagyalakshmi P_3	Pusa Komal P_4	TC-99-1 P_5
Length of main vine (cm)	307.96	434.56	48.42	51.79	73.3
Stem thickness (mm)	25.8	23.88	39.04	32.88	29.76
Number of branches per plant	11.8	12.64	9.52	8.28	6.48
Days for first flowering	60.48	60.4	39.92	40.8	40.64
Days to first harvest	79.04	77.44	55.6	55.52	54.92
Number of pods per plant	47.84	42.88	12.0	14.28	8.88
Number of seeds per pod	19.99	20.46	10.83	10.92	16.52
Average weight of pod (g)	20.54	14.89	6.99	6.01	8.11
Length of pod (cm)	50.558	47.23	25.61	22.09	17.16
Number of harvests	10.4	11.28	6.76	8.84	5.8
Duration of crop (days)	115.56	115.28	83.2	87.28	90.68
Pod yield/ plant (g)	902.85	638.8	83.91	85.89	72.13
Plant habit	Trailing	Trailing	Bush	Bush	Bush
Pod colour	Greenish white	Vine red	Greenish white	Greenish white	Green
Flower colour	Purple	Purple	White	Purple	White
Stem thickness	Green	Purplish	Green	Green	Green
Seed coat colour	Black	Brown	Mottled	Cream	Cream

Table 4.2 Analysis of variance for different yield components of parents

Source of variation	df	Mean sum of squares											
		Length of main vine	Stem thick-ness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
Treat ments	4	157820.8**	180.9**	31.8**	599.8**	788.1**	1731.2**	110.4**	193.8**	1200.0**	27.1**	1242.1**	758236.8**
Error	16	76.22	2.07	0.838	3.61	5.04	2.48	0.23	0.086	2.66	0.461	4.30	2570.97

*, ** : Significant at 5%, 1% respectively

Table 4.3 Mean, Range, Range over mean in five cowpea genotypes

Characters	Range				Mean	Range over mean (%)
	Genotype	Low	Genotype	High		
Length of main vine at final harvest (cm)	Bhagyalakshmi	48.42	Vyjayanthi	434.56	183.2	210.77
Stem thickness (mm)	Vyjayanthi	23.88	Bhagyalakshmi	39.04	30.27	50.08
Number of branches per plant	TC-99-1	6.48	Vyjayanthi	12.64	9.74	63.24
Days to first flowering	Bhagyalakshmi	39.9	Lola	60.48	48.45	42.47
Days to first harvesting	TC-99-1	54.9	Lola	79.04	64.50	37.42
Number of pods per plant	TC-99-1	8.88	Lola	47.84	25.18	154.72
Number of seeds per pod	Bhagyalakshmi	10.84	Vyjayanthi	20.47	15.75	61.14
Average weight of pod (g)	Pusa Komal	6.01	Lola	20.5	11.31	128.11
Length of pod (cm)	TC-99-1	17.16	Lola	50.56	32.5	102.76
Number of harvests	TC-99-1	5.8	Vyjayanthi	11.28	8.61	63.64
Duration of crop (days)	Bhagyalakshmi	83.2	Lola	115.56	98.4	32.88
Pod yield (g)	TC-99-1	72.14	Lola	902.85	356.7	232.88

47.84 (Lola) with a mean of 25.18. Maximum pod yield per plant was given by Lola (902.85 g) and minimum by TC-99-1 (72.1g). Mean value for pod yield was 356.7 g. Maximum coefficient of variation was observed for pod yield per plant (14.21) where as minimum recorded for length of the pod (1.95).

4.2 EXPERIMENT 2

In the present investigation, a new hybridization method was standardized for cowpea, which ensured a good pod set (80-85%). The method is explained in Plate 2. The F_1 seeds obtained from 5x5 diallel cross were collected and raised along with the parents in RBD with two replications during January to April 2004. The mean performances of these genotypes for the 12 traits are presented in Table 4.4. Twenty hybrids and five parents were evaluated. The analysis of variance indicated that significant differences were observed among genotypes for all the characters (Table 4.5).

4.2.1 Genetic parameters

Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability , genetic advance and genetic gain are presented in Table 4.6.

4.2.1.1 PCV and GCV

High PCV values were recorded for length of main vine at final harvest (67.47), number of pods per plant (31.18), average weight of pod (43.52), pod yield (75.43), number of branches per plant (25.89), length of pod (27.49) and number of harvests (20.75). Stem thickness (17.85), days for first flowering (12.12), days to first harvest (12.30), number of seeds per pod (14.53) and duration of crop (12.14) exhibited moderate PCV values. Highest GCV was recorded for pod yield followed by length of main vine at final harvest (60.75). Stem thickness (16.67), days for first flowering (11.92), days to first harvest (11.88), number of

Plate 2. New hybridization method adopted in the experiment

a. Emasculation

1. Selection of bud at correct stage
2. Holding bud between thumb and the forefinger
3. Incision on the standard petal
4. Removal of half portion of the bud
5. Removal of stamens

b. Pollination

1

2

3

4

5

b

Plate 2. New hybridization method adopted in the experiment

Table 4.4 Mean performances of F_1s for twelve characters

Sl.No	Genotypes	Length of main vine	Stem thickness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
1	P1 x P2	228.9	36.6	8.9	53.6	74.1	42.8	17.0	17.6	38.9	13.25	113	752.6
2	P1 x P3	175.5	37.7	9.1	44.3	60.8	30.8	16.3	10.9	34.6	12.9	109.8	335.7
3	P1 x P4	276.4	26.3	8.4	47.7	61.5	24.5	15.8	12.8	31.3	12.5	108.9	312.1
4	P1 x P5	222.6	28.8	7.1	47.1	62.3	28.8	13.4	11.1	32.6	12.3	117.9	324.8
5	P2 x P1	213.7	37.8	6.8	48.2	63.3	30.2	16.7	15.4	31.5	11.5	117.7	466.9
6	P2 x P3	148.3	28.0	7.0	40.8	53.8	32.0	15.8	11.0	35.2	12.7	107.5	351.4
7	P2 x P4	247.6	30.2	10.6	47.4	63.6	26.8	13.7	7.6	29.2	12.3	119.0	204.1
8	P2 x P5	153.9	19.8	8.6	46.0	61.0	32.8	14.0	10.9	32.6	10.6	106.9	358.4
9	P3 x P1	181.0	25.8	6.9	40.2	57.5	23.5	15.3	5.2	32.5	12.1	118.0	121.9
10	P3 x P2	71.0	37.5	7.5	46.5	61.5	30.0	18.0	9.4	34.1	11.0	119.0	280.4
11	P3 x P4	51.7	37.5	10.5	40.5	58.7	25.5	18.0	9.8	36.9	10.2	112.5	251.0
12	P3 x P5	62.3	27.9	6.9	38.7	53.1	23.7	15.8	4.6	21.1	7.8	103.6	105.9
13	P4 x P1	56.9	32.7	8.7	39.6	55.9	24.6	16.9	7.2	28.9	8.9	108.0	178.4
14	P4 x P2	233.8	41.5	8.3	45.3	61.5	24.5	17.0	7.9	31.2	10.2	99.5	192.8
15	P4 x P3	20.3	34.0	8.3	40.8	52.5	24.1	13.3	4.6	17.6	8.6	92.7	110.8
16	P4 x P5	82.5	35.5	8.2	38.0	54.0	23.3	18.0	6.6	28.9	10.8	93.8	153.7
17	P5 x P1	133.2	34.4	9.7	39.8	55.6	24.7	18.3	8.4	29.5	7.7	87.9	206.6
18	P5 x P2	312.3	34.8	13.4	39.3	56.4	26.9	16.1	5.0	24.9	12.6	116.1	134.7
19	P5 x P3	21.9	27.6	7.8	40.3	56.6	23.7	15.2	6.1	21.7	9.9	89.3	144.4
20	P5 x P4	90.3	25.8	10.2	39.1	52.3	25.6	16.2	5.6	19.1	9.2	86.2	144.7

P_1 - Lola P_2 -Vyjayanthi P_3 -Bhagyalakshmi P_4 -Pusa Komal P_5 -TC-99-1

Table 4.5 Analysis of variance for different yield components of parents & F_1s

Source of variation	df	Mean sum of squares											
		Length of main vine	Stem thick-ness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
Treat ments	24	25742.7**	58.7**	8.73**	67.9**	146.3**	237.5**	14.28**	39.23**	193.97**	12.23**	337.3**	130000.1**
Error	24	1869.5	5.3	1.8	0.95	3.3	6.2	0.79	0.28	1.1	0.82	7.8	1026.6

*, ** : Significant at 5%, 1% respectively

Table 4.6 Estimates of genetic parameters for different yield components (Parents and hybrids)

Sl.No	Yield characters	Mean	Broad sense heritability (%)	Narrow sense heritability (%)	Genetic advance	Genetic gain (%)	GCV (%)	PCV (%)
1.	Length of main vine	160.31	81.10	40.47	180.62	112.6	60.75	67.47
2.	Stem thickness	32.3	87.2	11.14	10.36	32.07	16.67	17.85
3.	Number of branches per plant	9.12	70.1	18.13	3.41	37.39	21.67	25.89
4.	Days for first flowering	44.11	96.7	43.0	10.65	24.14	11.92	12.12
5.	Days to first harvest	60.15	93.3	44.3	14.22	23.64	11.88	12.30
6.	Number of pods per plant	27.32	90.8	41.21	15.94	58.34	29.71	31.18
7.	Number of seeds per pod	15.74	86.5	41.17	4.08	25.92	13.52	14.53
8.	Average weight of pod	9.37	98.2	36.11	8.25	88.04	43.12	43.52
9.	Length of pod	30.33	98.7	47.54	16.95	55.88	27.31	27.49
10.	Number of harvests	10.81	85.6	30.02	3.95	36.54	19.20	20.75
11.	Duration of crop	105.65	95.5	34.67	25.23	23.88	11.86	12.14
12.	Pod yield	280.98	97.7	41.81	426.57	151.81	74.56	75.43

seeds per pod (29.71) and number of harvests (19.20) showed moderate GCV values. Low GCV values were not noticed for the characters studied.

4.2.1.2 Heritability

Heritability is a good index of the transmission of characters from parents to their offspring. Heritability is of two types, viz, broad sense heritability and narrow sense heritability.

High broad sense heritability estimates were observed for all the traits studied. Length of the pod recorded maximum heritability (98.7) followed by average weight of pod (98.2). High heritability was noticed for days for first flowering (96.7), duration of crop (95.5), pod yield (97.7) and days to first harvest (93.3).

Among the 12 characters studied, length of the pod (47.54) recorded highest narrow sense heritability. The traits like length of main vine at final harvest (40.5), days for first flowering (43.0), days to first harvest (44.3), number of pods per plant (41.21), number of seeds per pod (41.17) and pod yield (41.81) have high narrow sense heritability. The trait stem thickness (11.14) has lowest narrow sense heritability among the characters studied.

4.2.1.3 Genetic advance and Genetic gain

Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. High genetic advance was recorded for pod yield (426.57), length of main vine at final harvest (180.62) and duration of crop (25.23). Minimum value for genetic advance (3.41) was registered by number of branches per plant. Genetic gain is the difference between the men phenotypic value of the progeny of selected plants and the base or parental population. Genetic gain was maximum for pod yield (151.81) followed by length of main vine at final harvest (112.6). It was minimum for days to first harvest (23.64).

4.2.2 Association of characters

In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in required character. The phenotypic and genotypic correlations for twelve characters in 25 genotypes are presented in Table 4.7.

4.2.2.1 Correlation of yield and its attributes

Phenotypic Correlation

Phenotypic correlation values indicated that pod yield was positively correlated with average weight of pod (0.948), number of pods per plant (0.899), days for first flowering (0.866), days to first harvest (0.859), length of the pod (0.830), number of harvests (0.620) and length of main vine (0.605). Traits like stem thickness (-0.025) and number of branches per plant (0.081) had shown no significant correlation with pod yield.

Genotypic correlation

Pod yield showed high positive genotypic correlation with average weight of pod (0.957) followed by number of pods per plant (0.922), days to first harvest (0.919), days for first flowering (0.902), length of pod (0.847), length of main vine at final harvest (0.710), number of harvests (0.651) and duration of crop (0.616). Low genotypic correlation was noticed for number of seeds per pod (0.419).

4.2.2.2 Intercorrelation of yield attributes

Phenotypic correlation

Days for first flowering is positively correlated with days to first harvest (0.952), number of pods per plant (0.733), average weight of pod (0.851), length of pod (0.731), number of harvests (0.572), duration of crop (0.613) and pod yield (0.866). Number of pods per plant has shown positive correlation with number of

Table 4.7 Genotypic and phenotypic (lower and upper diagonal) correlations for twelve characters in parents and hybrids

Trait	Length of main vine	Stem thickness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
Length of main vine	**1.000**	-0.073	0.230	0.670**	0.687**	0.572**	0.279	0.586**	0.643**	0.662**	0.678**	0.605**
Stem thickness	-0.116	**1.000**	0.335	-0.058	-0.002	-0.104	0.181	0.042	0.059	-0.026	-0.007	-0.03
Number of branches per plant	0.254	0.382*	**1.000**	0.010	0.110	0.114	-0.034	0.020	0.175	0.180	0.050	0.081
Days for first flowering	0.783**	-0.065	0.035	**1.000**	0.952**	0.733**	0.206	0.851**	0.731**	0.572**	0.613**	0.866**
Days to first harvest	0.802**	-0.036	0.132	0.969**	**1.000**	0.738**	0.286	0.813**	0.784**	0.566**	0.612**	0.859**
Number of pods per plant	0.761**	-0.060	0.165	0.791**	0.824**	**1.000**	0.471*	0.763**	0.807**	0.701**	0.658**	0.899**
Number of seeds per pod	0.329	0.211	-0.031	0.218	0.315	0.542**	**1.000**	0.367	0.459**	0.193	0.315	0.393**
Average weight of pod	0.653**	0.028	0.025	0.880**	0.862**	0.814**	0.387*	**1.000**	0.798**	0.564**	0.573**	0.948**
Length of pod	0.715**	0.079	0.228	0.755**	0.830**	0.848**	0.490**	0.814**	**1.000**	0.702**	0.731**	0.830**
Number of harvests	0.831**	-0.042	0.177	0.630**	0.644**	0.763**	0.218	0.599**	0.772**	**1.000**	0.766**	0.620**
Duration of crop	0.730**	-0.012	0.083	0.652**	0.660**	0.719**	0.350	0.580**	0.751**	0.835**	**1.000**	0.602**
Pod yield	710**	-0.020	0.098	0.902**	0.919**	0.922**	0.419*	0.957**	0.847**	0.651**	0.616**	**1.000**

*, **: Significant at 5%, 1% respectively

seeds per pod (0.471), average weight of pod (0.763), length of pod (0.807), number of harvests (0.701) and duration of crop (0.658).

Genotypic correlation

Length of main vine at final harvest is positively correlated with days for first flowering (0.783), days to first harvest (0.802), number of pods per plant (0.761), average weight of pod (0.653), number of harvests (0.831) and duration of crop (0.730). Days for first flowering were positively correlated with days to first harvest (0.969), average weight of pod (0.880), length of pod (0.755) and number of pods per plant (0.791). Positive correlation was observed for length of pod with length of main vine (0.715), days for first flowering (0.755), days to first harvest (0.830), number of pods per plant (0.848) and average weight of pod (0.814).

4.2.2.3 Path coefficient analysis

Positive direct effect on pod yield per plant (Table 4.8) was exerted through number of pods per plant (1.880), length of main vine (1.656), average weight of pod (0.807), days to first harvest (0.677), length of the pod (0.668), stem thickness (0.565) and duration of crop (0.353). High negative direct effect was noticed for days for first flowering (-2.423) followed by number of harvests (-1.919), number of seeds per pod (-1.317) and number of branches per plant (-0.754). High indirect effects were noticed in length of the pod (1.593), days to first harvest (1.549), average weight of pod (1.530), days for first flowering (1.487) and length of main vine at final harvest (1.430).

4.2.3 Combining ability analysis

4.2.3.1 General combining ability

The average performance of a strain or genotype in a series of hybrid combinations is termed as general combining ability. The GCA variance is primarily a function of the additive genetic variance and this is due to allelic

Table 4.8 Direct and indirect effects of yield attributes on pod yield per plant in parents and hybrid population

Trait	Length of main vine	Stem thickness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop
Length of main vine	**1.656**	-0.065	-0.191	-1.897	0.543	1.430	-0.434	0.527	0.478	-1.594	0.258
Stem thickness	-0.191	**0.565**	-0.288	0.158	-0.024	-0.112	-0.279	0.023	0.053	0.081	-0.004
Number of branches per	0.420	0.216	**-0.754**	-0.086	0.089	0.310	0.040	0.020	0.152	-0.339	0.029
Days for first flowering	1.296	-0.037	-0.027	**-2.423**	0.656	1.487	-0.288	0.710	0.505	-1.209	0.230
Days to first harvest	1.328	-0.020	-0.099	-2.347	**0.677**	1.549	-0.414	0.695	0.554	-1.236	0.233
Number of pods per plant	1.259	-0.034	-0.124	-1.916	0.558	**1.880**	-0.714	0.657	0.566	-1.465	0.254
Number of seeds per pod	0.546	0.119	0.023	-0.529	0.213	1.019	**-1.317**	0.312	0.328	-0.418	0.124
Average weight of pod	1.081	0.016	-0.019	-2.133	0.584	1.530	-0.509	**0.807**	0.544	-1.149	0.205
Length of pod	1.184	0.045	-0.172	-1.830	0.562	1.593	-0.646	0.657	**0.668**	-1.481	0.265
Number of harvests	1.376	-0.024	-0.133	-1.527	0.436	1.435	-0.287	0.483	0.516	**-1.919**	0.295
Duration of crop	1.209	-0.007	-0.062	-1.580	0.447	1.351	-0.461	0.468	0.502	-1.603	**0.353**
Genetic correlation	0.710	-0.020	0.098	0.902	0.919	0.922	0.419	0.957	0.847	0.651	0.616

Residual = 0.0157

contribution. The *gca* helps in the selection of suitable parents (good general combiners) for hybridization.

Analysis of variance for combining ability (Table 4.9) showed that variance due to general combining ability *(gca)* was significant for all the characters studied.

4.2.3.2 Specific combining ability

The performance of a parent in a specific cross is known as specific combining ability. *sca* refers to the deviation of a particular cross from the general combining ability and it is mainly a function of dominance variance.

Analysis of variance for combining ability (Table 4.9) showed that variance due to specific combining ability *(sca)* were significant for all the characters except for number of branches per plant.

4.2.3.3 gca/sca ratio

A high *gca/sca* ratio indicates that the traits are highly heritable and can be fixed in the next generations. *gca/sca* ratio (Table 4.9) was high for traits like number of branches per plant (3.005), days to first harvest (2.43), length of pod (2.126), pod yield (1.98) and days for first flowering (1.807). The *gca/sca* ratio near to unity can use for heterosis and fix traits. The traits like number of seeds per pod (1.20), length of main vine at final harvest (1.101) and average weight of pod (1.094) have *gca/sca* ratio near to unity. Duration of crop (0.658), number of harvests (0.598) and stem thickness (0.596) have *gca/sca* ratio lower than unity.

4.2.3.3 General combining ability effects

General combining ability effects for twelve characters are presented in Table 4.10.

Table 4.9 Analysis of variance for combining ability, GCA and SCA variances, *gca-sca* ratio for twelve characters.

Source of variation	df	Length of main vine	Stem thickness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
gca	4	17683.01**	10.22*	5.01**	62.90**	167.09**	278.69**	11.70**	25.35**	222.4**	5.7**	170.5**	147052**
sca	10	16043.66**	17.16**	1.6	34.79**	68.49**	161.06**	9.7**	23.17**	104.59**	9.5**	258.9**	73903**
GCA variance		13230	3.825	0.91	34.11	76.03	150.4	8.045	17.07	117.18	5.47	169.1	725525
SCA variance		66285.9	73.17	4.5	143.74	278.23	656.4	14.61	97.29	430.74	38.34	1078.42	305184
gca/sca ratio		1.101	0.596	3.005	1.807	2.439	1.730	1.200	1.094	2.126	0.598	0.658	1.989

*, ** : Significant at 5%, 1% respectively

Table 4.10 General combining ability effects for twelve characters in five parents

Characters	Lola P_1	Vyjayanthi P_2	Bhagyalakshmi P_3	Pusa Komal P_4	TC-99-1 P_5
Length of main vine	46.16	59.56	-14.38	-40.72	-50.62
Stem thickness	-1.04	-0.39	-1.15	1.36	1.21
Number of branches per plant	1.17	0.10	-0.03	-0.03	-1.21
Days for first flowering	3.24	3.18	-1.61	-1.63	-3.18
Days to first harvest	5.03	5.44	-2.50	-2.83	-5.13
Number of pods per plant	6.10	7.63	-4.12	-4.21	-5.40
Number of seeds per pod	0.19	1.99	-0.35	-1.58	-0.25
Average weight of pod	2.00	2.10	-1.40	-0.88	-1.82
Length of pod	6.25	5.69	-2.05	-3.83	-6.06
Number of harvests	0.81	1.05	-0.76	-0.15	-0.95
Duration of crop	3.81	6.58	-2.92	-4.85	-2.68
Pod yield	162.75	151.32	-103.85	-75.38	-134.83

Length of main vine at final harvest

The parent P_2 exhibited maximum positive *gca* effect (59.56) and parent P_1 (46.16) exhibited minimum positive *gca* effect. The parent P_5 (-50.62) ranked first in negative *gca* effect and the parent P_3 (-14.38) recorded minimum negative *gca* effect.

Stem thickness

The parent P_4 (1.36) recorded maximum positive *gca* effect and the parent P_5 (1.21) exhibited minimum positive *gca* effect. Maximum negative *gca* effect was shown by parent P_3 and minimum negative effect by the parent P_2.

Number of branches per plant

P_1 exhibited the maximum positive *gca* effect (1.17) and P_2 recorded minimum positive *gca* effect. Maximum negative effect was shown by the parent P_5 (-1.21) and parents P_4 and P_3 were on par for the minimum negative effect (-0.03).

Days for first flowering

The parent P_1 (3.24) ranked first in positive *gca* effect followed by P_2 (3.18). The parent P_5 (-3.18) recorded maximum negative effect followed by P_4 (-1.63) and P_3 (-1.61).

Days to first harvest

The parent P_2 (5.44) exhibited maximum positive *gca* effect followed by P_1 (5.03). Maximum negative *gca* effect was recorded by P_5 (-5.13) and minimum negative *gca* effect by P_3 (-2.50).

Number of pods per plant

Positive *gca* effect was maximum for the parent P_2 (7.63) followed by the parent P_1 (6.10). P_5 (-5.40) exhibited maximum negative *gca* effect and P_3 recorded minimum negative *gca* effect (-4.12).

Number of seeds per pod

P_2 (1.99) recorded the maximum positive *gca* effect followed by P_1 (0.19). Negative effect was highest for P_4 (-1.58) and minimum for P_5 (-0.25).

Average weight of pod

The parent P_2 (2.10) ranked first in positive *gca* effect followed by P_1 (2.0). The maximum negative effect is exhibited by P_5 (-1.82) and minimum effect by P_4 (-0.88).

Length of the pod

P_1 (6.25) recorded maximum positive *gca* effect for length of the pod followed by P_2 (5.69). Maximum negative effect for this character is exhibited by P_5 (-6.06) and minimum effect by P_3 (-2.05).

Number of harvests

P_2 exhibited the maximum positive *gca* effect (1.05) and P_1 recorded minimum positive *gca* effect (0.81). Maximum negative effect was shown by the parent P_5 (-0.95) and minimum negative effect by parent P_4 (-0.03).

Duration of crop

P_2 (6.58) recorded maximum positive *gca* effect for duration of crop and minimum by P_1 (3.81). Maximum negative effect for this character is exhibited by P_4 (-4.85) and minimum effect by P_5 (-2.68).

Pod yield

The highest positive *gca* effect was recorded for P_1 (162.75) and was followed by P_2 (151.32). The maximum negative *gca* effect was exhibited by P_5 (-134.83) and minimum negative *gca* effect by P_4 (-75.38).

4.2.3.4 Specific combining ability effects

The specific combining ability effects of ten crosses for different characters were estimated and presented in Table 4.11

Table 4.11 Specific combining ability effects for twelve characters in cowpea

Hybrids	Length of main vine	Stem thickness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
$P_1 x P_2$	32.24	-0.81	0.23	2.46	1.62	4.98	0.22	2.95	3.89	0.85	5.79	172.70
$P_1 x P_3$	160.02	-2.88	-0.15	6.92	12.81	13.60	3.57	2.96	11.25	2.29	15.29	218.42
$P_1 x P_4$	-146.63	2.99	0.86	-8.11	-10.70	-15.75	-1.87	-5.76	-9.09	-3.85	-18.05	-372.75
$P_1 x P_5$	-136.91	1.02	0.74	-6.09	-7.80	-15.83	-5.96	-6.27	-12.72	-1.47	-20.01	-340.91
$P_2 x P_3$	-167.53	1.47	-2.32	-8.28	-12.88	-18.34	-0.07	-5.19	-19.50	-5.19	-17.87	-352.62
$P_2 x P_4$	16.69	3.34	-0.44	4.62	6.70	11.75	1.50	4.62	4.76	1.70	5.67	294.03
$P_2 x P_5$	-26.78	4.57	0.92	-3.16	-4.38	0.95	-0.50	-1.09	2.69	2.16	0.25	-63.48
$P_3 x P_4$	138.15	-6.23	-0.79	3.49	2.01	5.24	2.68	3.34	4.96	2.82	11.04	108.69
$P_3 x P_5$	94.25	-3.58	-0.86	4.43	5.06	10.74	-1.07	2.58	8.40	3.40	17.91	180.86
$P_4 x P_5$	111.66	2.95	-1.17	5.52	6.47	12.91	3.40	6.47	9.10	1.94	19.59	294.50

P_1 - Lola P_2 -Vyjayanthi P_3 -Bhagyalakshmi P_4 -Pusa Komal P_5 -TC-99-1

Length of the main vine at final harvest

Specific combining ability effect of P_1xP_3 (160.02) was maximum and positive for this character where as P_2xP_4 (16.69) exhibited minimum positive *sca* effect. Maximum negative *sca* effect was recorded by cross P_2xP_3 (-167.53) and minimum by P_2xP_5 (-26.78)

Stem thickness

The cross P_2xP_5 (4.57) recorded maximum positive *sca* effect and P_1xP_5 (1.02) exhibited minimum positive *sca* effect. Highest negative *sca* effect was recorded in P_3xP_4 (-6.23) and lowest in P_1xP_2 (-0.81).

Number of branches per plant

Maximum positive *sca* effect for number of branches per plant was observed for the cross P_1xP_4 (0.86) and minimum positive *sca* effect for P_1xP_2 (0.23).

Days for first flowering

The cross P_1xP_3 (6.92) recorded maximum positive *sca* effect and P_1xP_2 (2.46) recorded minimum positive *sca* effect. The cross P_2xP_3 (-8.28) exhibited maximum negative *sca* effect where P_2xP_5 (-3.16) recorded minimum negative *sca* effect for this character.

Days to first harvest

The cross P_1x P_3 (12.81) recorded maximum positive *sca* effect where as P_1xP_2 (1.62) recorded minimum positive value. P_2xP_3 (-12.88) exhibited maximum negative *sca* effect and P_2xP_5 (-4.38) showed minimum negative *sca* effect.

Number of pods per plant

The specific combining ability effects indicated that, the cross P_1xP_3 (13.60) has highest positive *sca* effect for this character and the cross P_2xP_5 (0.95) has lowest positive value. P_2xP_3 (-18.34) exhibited maximum negative *sca* effect and P_1xP_4 (-15.75) showed minimum negative *sca* effect.

Number of seeds per pod

The maximum positive *sca* effect for this trait was observed for P_1xP_3 (3.57) and minimum value for P_1xP_2 (0.22). The negative *sca* effect was highest for P_1xP_5 (-5.96) and lowest negative *sca* effect was for P_2xP_3 (-0.07)

Average weight of pod

The highest positive *sca* effect was noticed for P_4xP_5 (6.47) and lowest positive *sca* effect for P_3xP_5 (2.58). The maximum negative *sca* effect was observed for P_1xP_5 (-6.27) and minimum negative *sca* effect for P_2xP_5 (-1.09).

Length of the pod

The cross P_1xP_3 (11.25) recorded maximum positive *sca* effect for this character where as the cross P_2x P_5 (2.69) showed minimum positive *sca* effect. It was observed that the cross P_2xP_3 (-19.50) has maximum negative *sca* effect and the cross P_1xP_4 (-9.09) has minimum negative *sca* effect.

Number of harvests

The maximum positive *sca* effect for number of harvests observed for P_3xP_5 (3.40) and minimum positive effect for P_1xP_2 (0.85). The negative *sca* effect was highest for the cross P_2xP_3 (-5.19) and lowest for P_1xP_5 (-1.47).

Duration of crop

The cross P_4xP_5 (19.59) exhibited maximum positive *sca* effect and the cross P_2xP_5 (0.25) showed minimum positive *sca* effect. It was observed that the cross P_1xP_5 (-20.01) has maximum negative *sca* effect and the cross P_2xP_3 (-17.87) has minimum negative *sca* effect.

Pod yield

The specific combining ability effects indicated that P_4xP_5 (294.5) has highest positive *sca* effect for this character and the cross P_3xP_4 (108.69) has lowest positive *sca* effect. The negative *sca* effect was maximum for P_1xP_4 (-372.75) and minimum for P_2xP_5 (-63.48).

The cross P_1xP_2 exhibited good *sca* for main vine length and pod yield. The hybrid P_4xP_5 recorded good *sca* for duration of crop and number of pods per plant. Crosses like P_4xP_5, P_1xP_3 and P_2xP_4 showed good *sca* for number of pods per plant. Good *sca* effect in negative direction for main vine length was observed for $P_1x P_4$, $P_1x P_5$ and P_2xP_3.

4.2.4 Heterosis

Percentage of mid parent, better parent (heterobeltiosis) and standard heterosis for 10 hybrids in cowpea is presented in Table 4.12. The parent, Lola was taken as better parent and Vyjayanthi was taken as standard parent.

Length of the main vine at final harvest

The cross combination P_3xP_5 (247.08) recorded high positive heterobeltiosis where as the cross P_3xP_4 (195.14) expressed low positive heterobeltiosis. Highest negative heterobeltiosis (-61.51) was noted for the cross P_2xP_4 where as lowest negative heterobeltiosis for P_1xP_4 (-16.57). All crosses recorded high standard heterosis where as P_4xP_5 showed no heterosis and the cross P_1xP_2 expressed negative heterosis (-40.58).

Stem thickness

Highest positive heteribeltiosis was noticed for P_2xP_3 (38.83) where as minimum positive heterosis for P_2xP_4 (2.75). Negative heterobeltiosis was maximum for P_3xP_4 (-44.34) and was minimum for P_1xP_5 (-4.26). High positive standard heterosis was given by P_1xP_2 (34.4) and lowest by P_1xP_3 (5.82). Negative standard heterosis was maximum for P_3xP_4 (-40.81) and minimum for P_2xP_5 (-10.16).

Table 4.12 Percentage of midparent, better parent and standard heterosis for 10 hybrids in cowpea

Sl.No.	Hybrids	Length of main vine at final harvest			Stem thickness		
		MPH	BPH	SH	MPH	BPH	SH
1.	$P_1 \times P_2$	-36.11	-30.92	-40.58	27.77	21.76	34.4
2.	$P_1 \times P_3$	-8.46	-47.03	236.53	14.76	25.33	5.82
3.	$P_1 \times P_4$	44.23	-16.57	431.79	-17.27	-12.6	-21.49
4.	$P_1 \times P_5$	10.66	-32.81	213.52	-7.59	-4.26	-10.70
5.	$P_2 \times P_3$	-2.28	-44.52	309.71	20.33	38.83	6.19
6.	$P_2 \times P_4$	-32.17	-61.51	185.23	-7.82	2.75	-16.42
7.	$P_2 \times P_5$	10.18	-34.75	253.94	-2.61	6.33	-10.16
8.	$P_3 \times P_4$	195.6	195.14	196.13	-42.63	-44.34	-40.81
9.	$P_3 \times P_5$	193.5	247.08	154.93	-23.98	-27.58	-20.00
10.	$P_4 \times P_5$	15.47	36.60	0.00	14.07	11.94	16.28
Sl.No.	Hybrids	Number of branches per plant			Days to first flowering		
1.	$P_1 \times P_2$	-15.48	-17.44	-13.41	-4.52	-4.80	-4.24
2.	$P_1 \times P_3$	-17.73	-15.81	-19.56	-8.92	-21.36	8.18
3.	$P_1 \times P_4$	-18.84	-21.86	-15.58	-2.41	-15.32	15.15
4.	$P_1 \times P_5$	-19.44	-33.49	2.14	-2.97	-16.39	15.58
5.	$P_2 \times P_3$	-36.47	-33.37	-39.29	-0.64	-13.99	17.62
6.	$P_2 \times P_4$	-30.69	-31.71	-29.65	-16.35	-27.23	-1.63
7.	$P_2 \times P_5$	6.38	-10.49	31.07	-0.36	-13.93	18.28
8.	$P_3 \times P_4$	-19.06	-23.73	-13.77	11.48	12.12	10.84
9.	$P_3 \times P_5$	-24.38	-38.67	-1.43	-1.59	-1.83	-1.35
10.	$P_4 \times P_5$	-11.50	-24.62	7.14	13.17	12.25	14.11
Sl.No.	Hybrids	Days to first harvesting			Number of pods per plant		
1.	$P_1 \times P_2$	-5.62	-3.63	-7.54	-4.42	-7.65	-0.96
2.	$P_1 \times P_3$	-8.81	-21.02	7.86	2.47	-33.57	124.04
3.	$P_1 \times P_4$	-8.10	-20.04	8.04	-16.58	-47.07	96.79
4.	$P_1 \times P_5$	-5.53	-19.07	13.44	-2.44	-37.78	125.88
5.	$P_2 \times P_3$	-7.20	-21.00	12.44	6.05	-30.12	119.78
6.	$P_2 \times P_4$	-21.59	-32.95	-5.58	15.08	-25.87	157.03
7.	$P_2 \times P_5$	-6.07	-20.88	15.58	-6.47	-39.42	105.10
8.	$P_3 \times P_4$	7.58	8.15	7.01	150.24	138.62	163.05
9.	$P_3 \times P_5$	3.42	2.09	4.78	77.53	71.22	84.31
10.	$P_4 \times P_5$	10.02	8.04	12.07	138.10	140.96	135.29

Note: MPH- Mid-parent heterosis
SH -Standard heterosis
BPH- Better parent heterosis

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

continued.

Sl.No.	Hybrids	Number of seeds per pod			Average weight of pod		
		MPH	BPH	SH	MPH	BPH	SH
1.	$P_1 \times P_2$	-5.56	-2.86	-8.11	3.14	-6.47	14.94
2.	$P_1 \times P_3$	11.36	-6.68	38.05	-15.6	-41.88	54.10
3.	$P_1 \times P_4$	19.13	-9.53	74.37	4.74	-31.95	127.23
4.	$P_1 \times P_5$	-21.46	-23.33	-19.49	-14.86	-41.03	53.12
5.	$P_2 \times P_3$	9.89	-9.92	40.87	38.45	1.31	118.59
6.	$P_2 \times P_4$	14.79	-14.43	74.34	5.22	-28.02	95.56
7.	$P_2 \times P_5$	-22.29	-26.14	-18.00	-33.83	-51.26	2.99
8.	$P_3 \times P_4$	33.89	18.33	54.17	72.57	54.81	94.93
9.	$P_3 \times P_5$	7.60	29.59	-8.00	-27.57	-26.8	-28.32
10.	$P_4 \times P_5$	39.84	98.24	8.02	45.67	66.49	29.48
Sl.No.	Hybrids	Length of the pod			Number of harvests		
1.	$P_1 \times P_2$	-18.84	-19.17	-18.52	0.47	-0.93	1.92
2.	$P_1 \times P_3$	-6.14	-28.10	35.11	23.94	-3.44	73.01
3.	$P_1 \times P_4$	-7.62	-34.86	58.75	12.06	-6.06	38.84
4.	$P_1 \times P_5$	0.93	-32.33	98.48	29.15	-7.66	114.78
5.	$P_2 \times P_3$	-14.16	-34.05	22.93	12.39	-11.54	54.05
6.	$P_2 \times P_4$	4.53	-26.11	78.62	15.65	-1.92	40.88
7.	$P_2 \times P_5$	-7.42	-37.80	80.98	39.09	0.31	126.78
8.	$P_3 \times P_4$	43.73	27.28	65.07	28.19	41.80	16.96
9.	$P_3 \times P_5$	54.78	26.97	98.18	83.13	62.09	110.43
10.	$P_4 \times P_5$	88.73	72.77	107.93	48.65	21.55	91.30
Sl.No.	Hybrids	Duration of crop			Pod yield		
1.	$P_1 \times P_2$	-7.25	-7.25	-7.25	-1.58	-13.43	14.04
2.	$P_1 \times P_3$	5.33	-9.92	26.78	-30.56	-61.39	245.03
3.	$P_1 \times P_4$	4.37	-10.64	25.46	-33.53	-64.10	348.04
4.	$P_1 \times P_5$	10.60	-3.23	29.03	-31.39	-62.64	319.07
5.	$P_2 \times P_3$	12.92	-3.42	35.93	23.33	-29.25	379.98
6.	$P_2 \times P_4$	3.07	-11.76	23.88	-3.68	-46.76	404.42
7.	$P_2 \times P_5$	11.16	-2.73	29.69	-47.14	-70.47	151.46
8.	$P_3 \times P_4$	23.36	23.51	23.21	329.43	268.47	414.56
9.	$P_3 \times P_5$	32.63	36.31	29.14	39.42	25.25	57.20
10.	$P_4 \times P_5$	33.60	37.14	30.23	281.06	302.53	261.77

Note: MPH - Mid-parent heterosis
SH - Standard heterosis
BPH - Better parent heterosis

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

Number of branches per plant

All the hybrids recorded negative heterobeltiosis and values were maximum for P_3xP_5 (-38.67) and minimum for P_2xP_5 (-10.49). Maximum positive standard heterosis was expressed by P_2xP_5 (31.07) and minimum by P_1xP_5 (2.14). Negative standard heterosis was maximum for P_2xP_3 (-39.29) and minimum (-1.43) for P_3xP_5.

Days for first flowering

All the hybrids recorded negative heterobeltiosis except P_4xP_5 (12.25) and P_3xP_4 (12.12). Maximum negative heterobeltiosis was exhibited by P_2xP_4 (-27.23) and minimum by P_3xP_5 (-1.83). Positive standard heterosis was maximum for P_2xP_5 ('18.28) and minimum for P_1xP_3 (8.18).

Days to first harvest

Positive heterobeltiosis was maximum for P_3xP_4 (8.15) and minimum for P_3xP_5 (2.09). Negative heterobeltiosis was maximum for P_2xP_4 (-32.95) and minimum for P_1xP_2 (-3.63). All hybrids exhibited positive standard heterosis except P_1xP_2 (-7.54) and P_2xP_4 (-5.58).

Number of pods per plant

The hybrid P_4xP_5 (140.96) recorded maximum positive heterobeltiosis, where as minimum was noticed for P_3xP_5 (71.22). Negative heterobeltiosis was maximum for P_1xP_4 (-47.07) and minimum for P_1xP_2 (-7.65). All crosses showed high positive standard heterosis except P_1xP_2 (-0.96).

Number of seeds per pod

Highest positive heterobeltiosis was noticed for P_4xP_5 (98.24) where as minimum positive heterosis for P_3xP_4 (18.33). Negative heterobeltiosis was maximum for P_2xP_5 (-26.14) and was minimum for P_1xP_2 (-2.86). High positive standard heterosis was given by P_1xP_4 (74.37) and lowest by P_4xP_5 (8.02). Negative standard hete rosis was maximum for P_1xP_5 (-19.49) and minimum for P_3xP_5 (-8.0).

Average weight of pod

The hybrid P_4xP_5 exhibited maximum positive heterobeltiosis (98.24) where as P_2xP_3 (1.31) recorded minimum p[ositive heterobeltiosis . Negative heterobeltiosis was maximum for P_2xP_5 (-51.26) and minimum for P_1xP_2 (-6.47). All hybrids recorded positive standard heterosis except P_3xP_5 (-28.32). Maximum positive standard heterosis was observed for P_1xP_4 (127.23) and minimum for P_2xP_5 (2.99).

Length of the pod

Highest positive heterobeltiosis was noticed for P_4xP_5 (72.77) where as minimum positive heterosis for P_3xP_5 (26.97). Negative heterobeltiosis was maximum for P_2xP_5 (-37.8) and was minimum for P_1xP_2 (-19.17). High positive standard heterosis was given by P_4xP_5 (107.93) and lowest by P_2xP_3 (22.93). Standard heterosis was positive for all hybrids except for P_1xP_2 (-18.52).

Number of harvests

The cross combination P_3xP_5 (62.09) ranked first for positive heterobeltiosis and P_2xP_5 (0.31) ranked last. Negative heterobeltiosis was maximum for P_2xP_3 (-11.54) and minimum for P_1xP_2 (-0.93). For standard heterosis all hybrids showed positive values, and maximum standard heterposis was recorded by P_2xP_5 (126.78) and minimum by P_1xP_2 (1.92).

Duration of crop

Maximum positive heterobeltiosis was exhibited by P_4xP_5 (37.14) and minimum by P_3xP_4 (23.51). Nehgative heterobeltiosis was maximum for P_2xP_4 (-11.76) and minimum for P_2xP_5 (-2.73). Only P_1xP_2 expressed negative heterobeltiosis (-7.25). Maximum positive standard heterosis was for P_2xP_3 (35.93) and minimum for P_3xP_4 (23.21).

Pod yield

Highest positive heteribeltiosis was noticed for P_4xP_5 (302.53) where as minimum positive heterosis for P_3xP_5 (25.25). Negative heterobeltiosis was maximum for P_2xP_5 (-70.47) and was minimum for P_1xP_2 (-13.43). All hybrids expressed positive standard heterosis. High positive standard heterosis was given by P_3xP_4 (414.56) and lowest by P_1xP_2 (14.04).

4.2.5 *Inbreeding depression*

The inbreeding depression (expressed in percentage) in 10 crosses for 12 characters is presented in Table 4.13. The hybrid P_2xP_3 (90.49) expressed high inbreeding depression for length of main vine at final harvest. For stem thickness, the hybrid P_4xP_5 (31.20) exhibited high inbreeding depression. In case of days to first flowering maximum inbreeding depression (24.48) was expressed by the hybrid P_1xP_2. P_1xP_2 (40.35) recorded maximum inbreeding depression in case of number of pods per plant. The hybrid P_2xP_3, expressed maximum inbreeding depression in case of average weight of pod (70.25) and length of pod (43.97). Results indicated that P_2 xP_5 recorded maximum inbreeding depression in case of number of harvests. In he case of pod yield, maximum inbreeding depression (76.27) was observed in hybrid P_2xP_3.

4.3 EXPERIMENT 3

The F_2 population was raised from the seeds obtained from Experiment 2. Statistical analysis of the data was done for ANOVA and significant differences within and between each treatment was observed. Chi-square test was done for segregation of characters.

4.3.1 *Inheritance of plant habit in cowpea*

The inheritance of plant habit was worked out for 20 crosses and ratios were tested using the chi-square test for different genetic ratios (Table 4.14). In cross combinations involving bush cowpea and yard long bean as parents, its F_1 was semi-trailing nature. F_2 plants of this cross produced segregants with a ratio of 3:1 for trailing and bushy types. In crosses involving bush types as parents most of the progenies in F_2 were bush type except in the cross P_4xP_3.

Table 4.13 Percentage of inbreeding depression for ten hybrids in cowpea

Hybrids	Length of main vine	Stem thickness	Number of branches per plant	Days for first flowering	Days to first harvest	Number of pods per plant	Number of seeds per pod	Average weight of pod	Length of pod	Number of harvests	Duration of crop	Pod yield
$P_1 x P_2$	77.43	-2.39	-18.31	24.48	20.86	40.35	-5.88	-5.88	5.05	23.28	0.44	66.65
$P_1 x P_3$	64.50	25.93	23.76	12.64	12.67	23.09	3.05	3.05	39.08	39.61	5.64	68.47
$P_1 x P_4$	32.89	-61.60	-90.48	9.85	4.07	-27.55	0.52	0.52	-17.13	0.52	-4.72	1.75
$P_1 x P_5$	-5.01	-44.10	-15.38	3.93	1.20	14.93	-26.71	-26.71	3.99	17.00	15.61	40.66
$P_2 x P_3$	90.49	10.12	-22.25	15.29	17.18	20.02	19.99	19.99	43.97	25.43	21.17	76.27
$P_2 x P_4$	44.35	-26.79	-16.64	6.75	-0.47	27.09	-13.71	-13.71	18.03	15.69	12.72	56.25
$P_2 x P_5$	47.00	-18.72	-5.72	17.43	12.34	5.54	-34.18	-34.18	0.62	40.95	25.77	-6.00
$P_3 x P_4$	-102.9	-75.49	-56.18	14.41	7.41	17.86	-15.48	-15.48	23.48	-19.04	-8.59	62.41
$P_3 x P_5$	87.90	-6.98	-13.04	-0.25	1.57	-0.85	1.09	1.09	33.19	18.18	24.32	-18.51
$P_4 x P_5$	-27.24	31.20	-36.00	15.91	14.96	14.67	10.19	10.19	43.89	16.36	27.56	48.41

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

Table 4.14 Segregation pattern for plant habit of cowpea in F_2 generations

Crosses	Plant habit of			Total number of F_2 plants observed	Segregation for plant habit in F_2 generation		Expected phenotypic ratio	Chi-square value
	Female parent	Male parent	F_1 generation		Number of trailing	Number of nontrailing	Trailing : nontrailing	
P_1x P_2	trailing	trailing	trailing	15	12	3	3:1	0.33
P_1x P_3	trailing	nontrailing	trailing	15	12	3	3:1	0.33
P_1x P_4	trailing	nontrailing	trailing	15	11	4	3:1	-
P_1x P_5	trailing	nontrailing	trailing	15	12	3	3:1	0.33
P_2x P_3	trailing	nontrailing	trailing	15	13	2	3:1	0.33
P_2x P_4	trailing	nontrailing	trailing	15	9	6	3:1	1.00
P_2x P_5	trailing	nontrailing	trailing	15	8	7	3:1	1.00
P_3x P_4	nontrailing	nontrailing	trailing	15	7	8	3:1	4.33
P_3x P_5	nontrailing	nontrailing	nontrailing	15	-	All nontrailing	-	-
P_4x P_5	nontrailing	nontrailing	nontrailing	15	12	3	3:1	0.33
P_2 x P_1	trailing	trailing	trailing	15	9	6	3:1	1.00
P_3x P_1	nontrailing	trailing	trailing	15	12	3	3:1	0.33
P_4 x P_1	nontrailing	trailing	trailing	15	10	5	3:1	0.33
P_5 x P_1	nontrailing	trailing	nontrailing	15	9	6	3:1	1.00
P_3 x P_2	nontrailing	trailing	trailing	15	8	7	3:1	1.00
P_4 x P_2	nontrailing	trailing	nontrailing	15	8	7	3:1	1.00
P_5 x P_2	nontrailing	trailing	trailing	15	5	10	3:1	2.33
P_4 x P_3	nontrailing	nontrailing	nontrailing	15	1	14	All nontrailing	0.06
P_5 x P_3	nontrailing	nontrailing	nontrailing	15	3	12	3:1	10.33 *
P_5 x P_4	nontrailing	nontrailing	nontrailing	15	3	12	3:1	10.33 *

* significant difference from the expected phenotypic ratio

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

4.3.2 Inheritance of stem colour in cowpea

The inheritance pattern of stem colour in cowpea was worked out for 20 crosses and presented in Table 4.15. The F_2 segregants of cross P_2xP_5 were purple in stem colour where as the segregants of crosses, P_1xP_3 and P_4xP_1 exhibited green stem colour. The F_2 segregants of all other crosses exhibited stem pigmentation in a dihybrid ratio of 9:7 (purple:green).

4.3.3 Inheritance of flower colour in cowpea

Inheritance of flower colour in cowpea was presented in Table 4.16. F_2 segregants of crosses like P_4xP_3, P_5xP_1, P_2xP_5, P_5xP_2 and P_5xP_4 exhibited a monohybrid ratio of 3:1 (purple:white) in the present study. In a cross involving both parents with white flowers (P_3xP_5), all F_2 segregants expressed purple colour in flower where as the reciprocal cross gave segregants in different pattern. In case of crosses where one of the parents with purple flowers, the F_2 segreganats will be purple except in F_2 segregants of crosses P_4xP_3, P_2xP_5, P_5xP_2, P_3xP_4 and P_5xP_1.

4.3.4 Inheritance of pod colour in cowpea

Inheritance of pod colour in cowpea was presented in Table 4.17. A 3:1 monohybrid ratio was observed for pod pigmentation in crosses like P_1xP_2, P_2xP_3, P_3xP_2, P_2xP_4, P_4xP_2, P_1xP_4, P_1xP_5, P_5xP_1, P_3xP_4, P_4xP_3, P_5xP_3 and P_5xP_4. F_2 segregants of crosses like P_3xP_5, P_4xP_1 and P_1xP_3 exhibited green pod colour where F_2 segregants of P_2xP_1, P_2xP_5, P_5xP_2, P_3xP_1 and P_4xP_5 expressed purple pod colour.

4.3.5 Inheritance of seed colour in cowpea

Segregation pattern for seed coat colour of cowpea in F_2 generations are presented in (Table 4.18). F_2 segregants of all crosses except P_1xP_3 (all black),

Table 4.15 Segregation pattern for stem colour of cowpea in F_2 generations.

Crosses	Stem colour			Total number of F_2 plants observed	Segregation for stem colour in F_2 generation		Expected phenotypic ratio	Chi-square value
	Female parent	Male parent	F_1 generation		Number of purplish plants	Number of green plants	Purplish : green	
P_1x P_2	green	purplish	green	15	11	4	9:7	1.73
P_1x P_3	green	green	green	15	Nil	All green	All green	-
P_1x P_4	green	green	green	15	3	12	9:7	5.34
P_1x P_5	green	green	green	15	8	7	9:7	0.11
P_2x P_3	purplish	green	purplish	15	8	7	9:7	0.11
P_2x P_4	purplish	green	purplish	15	12	3	9:7	3.28
P_2x P_5	purplish	green	purplish	15	All purple	Nil	All purple	-
P_3x P_4	green	green	purplish	15	9	6	9:7	0.143
P_3x P_5	green	green	green	15	Nil	All green	All green	-
P_4x P_5	green	green	purplish	15	14	1	All purple	0.06
P_2 x P_1	purplish	green	purplish	15	10	5	9:7	0.68
P_3x P_1	green	green	green	15	1	14	All green	0.06
P_4 x P_1	green	green	green	15	Nil	All green	All green	-
P_5 x P_1	green	green	green	15	4	11	9:7	1.73
P_3 x P_2	green	purplish	green	15	10	5	9:7	0.68
P_4 x P_2	green	purplish	purplish	15	10	5	9:7	0.68
P_5 x P_2	green	purplish	purplish	15	11	4	9:7	1.73
P_4 x P_3	green	green	purplish	15	8	7	9:7	0.11
P_5 x P_3	green	green	green	15	2	13	9:7	5.34
P_5 x P_4	green	green	green	15	8	7	9:7	0.11

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

Table 4.16 Segregation pattern for flower colour of cowpea in F_2 generations

Crosses	Flower colour			Total number of F_2 plants observed	Segregation for flower colour in F_2 generation		Expected phenotypic ratio	Chi-square value
	Female parent	Male parent	F_1 generation		Number of purple	Number of white	Purple : white	
P_1x P_2	purple	purple	purple	15	14	1	All purple	0.06
P_1x P_3	purple	white	purple	15	All purple	Nil	All purple	-
P_1x P_4	purple	purple	purple	15	14	1	All purple	0.06
P_1x P_5	purple	white	purple	15	All purple	Nil	All purple	-
P_2x P_3	purple	white	purple	15	All purple	Nil	All purple	-
P_2x P_4	purple	purple	purple	15	14	1	All purple	0.06
P_2x P_5	purple	white	purple	15	11	4	3:1	-
P_3x P_4	white	purple	purple	15	14	1	All purple	0.06
P_3x P_5	white	white	purple	15	14	1	All purple	0.06
P_4x P_5	purple	white	purple	15	14	1	All purple	0.06
P_2 x P_1	purple	purple	purple	15	All purple	Nil	All purple	-
P_3x P_1	white	Purple	purple	15	All purple	Nil	All purple	-
P_4 x P_1	purple	purple	purple	15	All purple	Nil	All purple	-
P_5 x P_1	white	purple	white	15	10	5	3:1	0.33
P_3 x P_2	white	purple	purple	15	All purple	Nil	All purple	-
P_4 x P_2	purple	purple	purple	15	All purple	Nil	All purple	-
P_5 x P_2	white	purple	purple	15	12	3	3:1	0.33
P_4 x P_3	purple	white	purple	15	13	2	3:1	0.33
P_5 x P_3	white	white	white	15	6	9	3:1	4.03
P_5 x P_4	white	purple	purple	15	10	4	3:1	0.33

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

Table 4.17 Segregation pattern for pod colour of cowpea in F_2 generations.

Crosses	Pod colour			Total number of F_2 plants observed	Segregation for pod colour in F_2 generation		Expected phenotypic ratio	Chi-square value
	Female parent	Male parent	F_1 generation		Number of purple	Number of green	Purple:green	
$P_1 x P_2$	green	purple	Purple	15	8	7	3:1	1.00
$P_1 x P_3$	green	green	Green	15	Nil	All green	All green	-
$P_1 x P_4$	green	green	Green	15	3	12	3:1	0.33
$P_1 x P_5$	green	green	Purple	15	10	5	3:1	0.33
$P_2 x P_3$	purple	green	Purple	15	11	4	3:1	-
$P_2 x P_4$	purple	green	Purple	15	13	2	3:1	0.33
$P_2 x P_5$	purple	green	Purple	15	All purple	Nil	All purple	-
$P_3 x P_4$	green	green	Purple	15	13	2	3:1	0.33
$P_3 x P_5$	green	green	Green	15	Nil	All green	All green	-
$P_4 x P_5$	green	green	Purple	15	14	1	All purple	0.06
$P_2 x P_1$	purple	green	Purple	15	14	1	All purple	0.06
$P_3 x P_1$	green	green	purple	15	1	14	All green	0.06
$P_4 x P_1$	green	green	Green	15	Nil	All green	All green	-
$P_5 x P_1$	green	green	Green	15	4	11	3:1	-
$P_3 x P_2$	green	purple	purple	15	8	7	3:1	-
$P_4 x P_2$	green	purple	purple	15	9	6	3:1	-
$P_5 x P_2$	green	purple	purple	15	All purple	Nil	All purple	-
$P_4 x P_3$	green	green	Green	15	4	11	3:1	-
$P_5 x P_3$	green	green	Green	15	2	13	3:1	0.33
$P_5 x P_4$	green	green	Green	15	8	7	3:1	1.00

P_1 - Lola P_2 - Vyjayanthi P_3 - Bhagyalakshmi P_4 - Pusa Komal P_5 - TC-99-1

Table 4. 18 Segregation pattern for seed coat colour of cowpea in F_2 generations

Crosses	Seed coat colour			Total number of F_2 plants observed	Segregation for seed coat colour in F_2 generation			Expected *phenotypic* ratio	Chi-*square* value
	Female parent	Male parent	F_1 generation						
P_1x P_2	black	brown	black	15	9 black	6 brown	-	12:3:1	3.75
P_1x P_3	black	mottled	black	15	15 black	-	-	-	-
P_1x P_4	black	cream	black	15	12 black	3 brown	-	12:3:1	5.33
P_1x P_5	black	cream	black	15	8 black	5 cream	3 brown	12:3:1	2.63
P_2x P_3	brown	mottled	brown	15	9 mottled	6 brown	-	12:3:1	3.75
P_2x P_4	brown	cream	brown	15	12 brown	3 cream	-	12:3:1	-
P_2x P_5	brown	cream	brown	15	12 brown	3 cream	-	12:3:1	-
P_3x P_4	mottled	cream	brown	15	13 cream	2 brown	-	12:3:1	44.38 *
P_3x P_5	mottled	cream	mottled	15	15 cream	-	-	-	-
P_4x P_5	cream	cream	brown	15	15 brown	-	-	-	-
P_2 x P_1	brown	black	black	15	9 black	6 brown	-	12:3:1	3.75
P_3x P_1	mottled	black	black	15	12 mottled	2 cream	1 black	12:3:1	2.33
P_4 x P_1	cream	black	black	15	11black	4 cream	-	12:3:1	2.52
P_5 x P_1	cream	black	black	15	10 cream	2 brown	3 black	12:3:1	1.33
P_3 x P_2	mottled	brown	brown	15	13 brown	2cream	-	12:3:1	2.41
P_4 x P_2	cream	brown	brown	15	15 brown	-	-	-	-
P_5 x P_2	cream	brown	black	15	9 cream	5 brown	1 mottled	12:3:1	2.08
P_4 x P_3	cream	mottled	brown	15	9 cream	6 brown	-	12:3:1	28.75 *
P_5 x P_3	cream	mottled	mottled	15	15 cream	-	-	-	-
P_5 x P_4	cream	cream	black	15	12 cream	3 brown	-	-	-

* significant difference from the expected phenotypic ratio

P_1 - Lola　　P_2 - Vyjayanthi　　P_3 - Bhagyalakshmi　　P_4 - Pusa Komal　　P_5 - TC-99-1

P_4xP_2 and P_4xP_5 (all brown), P_3xP_5 and P_5xP_3 (all cream) and P_5xP_4 (12 cream: 3 brown) exhibited segregation ratio of 12:3:1 for seed coat colour.

Discussion

5. DISCUSSION

Vegetable cowpea (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) locally called, as 'Kurutholapayar' is a popular and remunerative vegetable of Kerala. The trailing varieties of cowpea are generally high yielding with protracted flowering and fruiting. The pods are either long or extra long. The bush varieties of cowpea are also popular, which are non-trailing. The cost of cultivation per unit area of trailing types is comparatively higher when compared to bush types, since the bush type needs no standards or *pandals*. The vegetable cowpea with semi trailing habit having the characters of 'Kurutholapayar', and tolerant to pest and diseases will have good consumer acceptability and it will give high returns to the farmers. With this background, the study was initiated to give an insight into the genetics of the trailing nature and its inheritance pattern with bush types.

5.1 VARIABILITY

The variability expressed among the parents to be taken for hybridization can be studied by means of measures of dispersion. Variability due to genetic and environmental factors decides their interaction effects. The influence of genetic and environment factors on expressed variability can be preliminary studied by estimating the range of variability, mean and coefficient of variation. The five cowpea genotypes used for hybridization in the present investigation exhibited significant differences among the parents for all the traits. Vyjayanthi and Lola exhibited all the trailing type characteristics where as Bhagyalakshmi, Pusa Komal and TC-99-1 expressed bush type characteristics.

5.2 GENETIC PARAMETERS

The influence of genetic and environmental factors on the expression of different characters among the population can be studied by determining the magnitude of PCV, GCV, heritability, genetic advance and expected genetic gain. The trends of above parameters are represented in Fig.5.1. The 20 hybrids and five

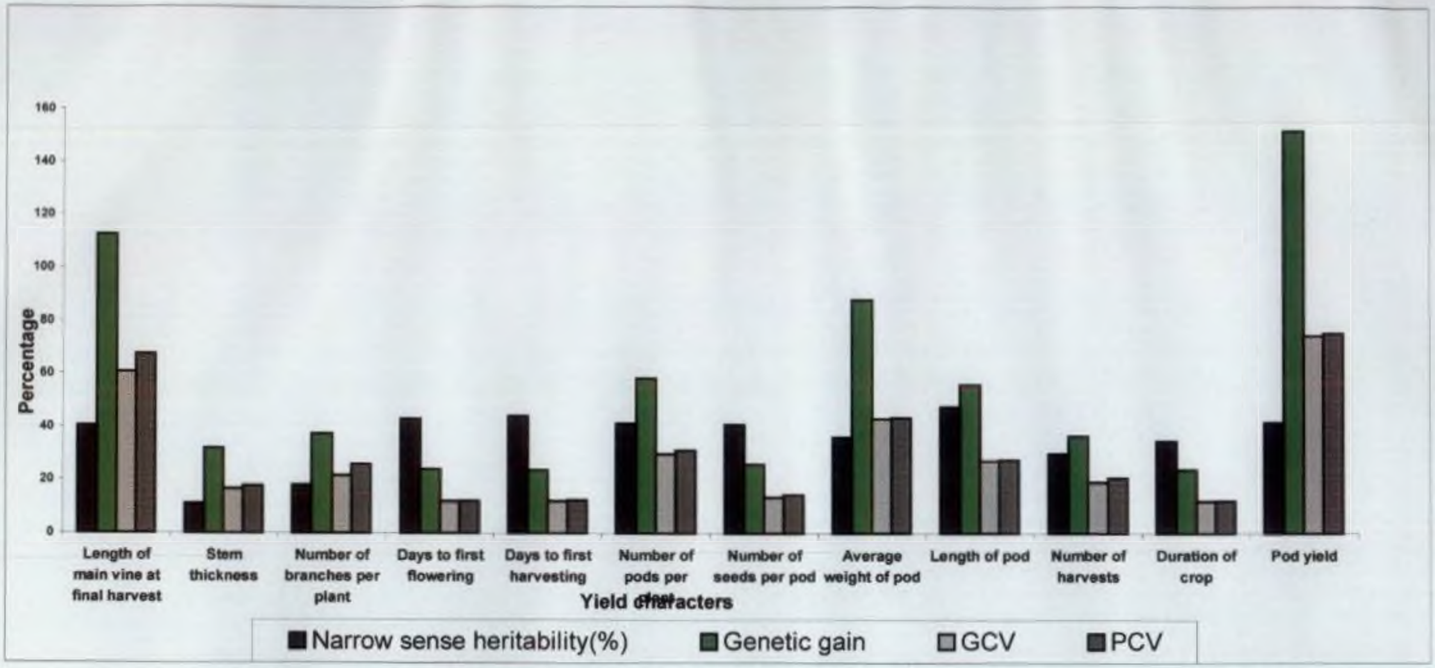

Fig. 5.1 PCV,GCV, Narrow sense heritability and genetic gain in parents and hybrids

LMV - Length of main vine ST - Stem thickness NBP - Number of branches/plant DFF - Days for first flowering DFH - Days to first harvest NPP - Number of pods/plant NSP - Number of seeds/pod AWP - Average pod weight LP - Pod length NH - Number of harvests DC -Crop duration PY - Pod yield parents used for this investigation showed significant differences among all the characters studied.

Maximum GCV, PCV and comparatively better narrow sense heritability was expressed by the pod yield and number of pods per plant. This indicated that these characters were mainly influenced by allelic contribution. This is in conformity with reports stated by Jyothi (2001) and Vidya *et al.* (2002). High PCV and medium GCV for number of harvests indicated the influence of environment on this character expression. High PCV and GCV were recorded for length of main vine at final harvest and number of branches per plant and this was suggestive for greater magnitude of variability on these traits. Similar findings were observed by Anbuselvam *et al.* (2000) and Vardhan and Savithramma (1998). Moderate GCV for number of seeds per pod was observed in the present study. This was supported by Tyagi *et al.* (2000) and Rewale *et al.* (1995).

Length of main vine at final harvest, duration of crop and pod yield exhibited high heritability accompanied with high genetic advance and this indicated that most likely the heritability is due to additive gene effects and selection may be effective for the improvement of these characteristics. High heritability and genetic advance for plant height was reported by Tyagi *et al.* (2000) and Anbuselvam *et al.* (2000). High heritability accompanied with low genetic advance was expressed in case of number of branches per plant, number of seeds per pod, average weight of pod and number of harvests. Selection for these traits may not be rewarding due to favorable influence of environment rather than genotype. Duration of crop showed moderate coefficient of variation with high heritability and genetic advance. Narrow sense heritability estimates for length of pod, days to first flowering and days to first harvesting were highly revealing that additive genes largely governed these characters. Heritability estimates for stem thickness and number of branches per plant was low in narrow sense, indicating the preponderance of non-additive gene action and heterosis breeding may be useful.

5.3 ASSOCIATION OF CHARACTERS

Association between yield and yield attributes gives the idea about the kind of relationship among characters, which plays major role in selection of characters for improving yield. The low heritable characters, effectively improved by indirect selection (correlated response give the trait chosen for indirect selection) had high heritability and high genetic correlation with the trait to be improved.

5.3.1 Correlation

Linearity of phenotypic and genotypic correlation was observed for most of the traits indicating that most of the traits are controlled by its genetic factors. Fig.5.2 represents the character association in parents and hybrids. The correlation studies, in general, showed higher magnitude of genotypic correlation coefficients than the phenotypic ones for most of the characters studied, there by establishing inherent genetic relationship among the characters.

The characters like length of main vine at final harvest, number of branches per plant, days to first flowering, days to first harvesting, number of pods per plant, number of seeds per pod, average weight of pod, length of the pod, number of harvests and duration of crop exhibited positive significant genotypic correlation with pod yield where as number of branches per plant not showed positive significant correlation. Vidya (2000), Kutty *et al.* (2003) and Bastian *et al.* (2001) reported similar relationships in cowpea. This finding indicates that pod yield per plant can increase by selecting the genotypes with the above mentioned characters. All the traits exhibited positive genotypic correlation with pod yield except stem thickness. Length of main vine at final harvest showed positive significant correlation with days to first flowering, days to first harvesting, number of pods per plant, average weight of pod, length of pod, number of harvests and duration of crop. It is favorable because it helps in simultaneous improvement of these characters.

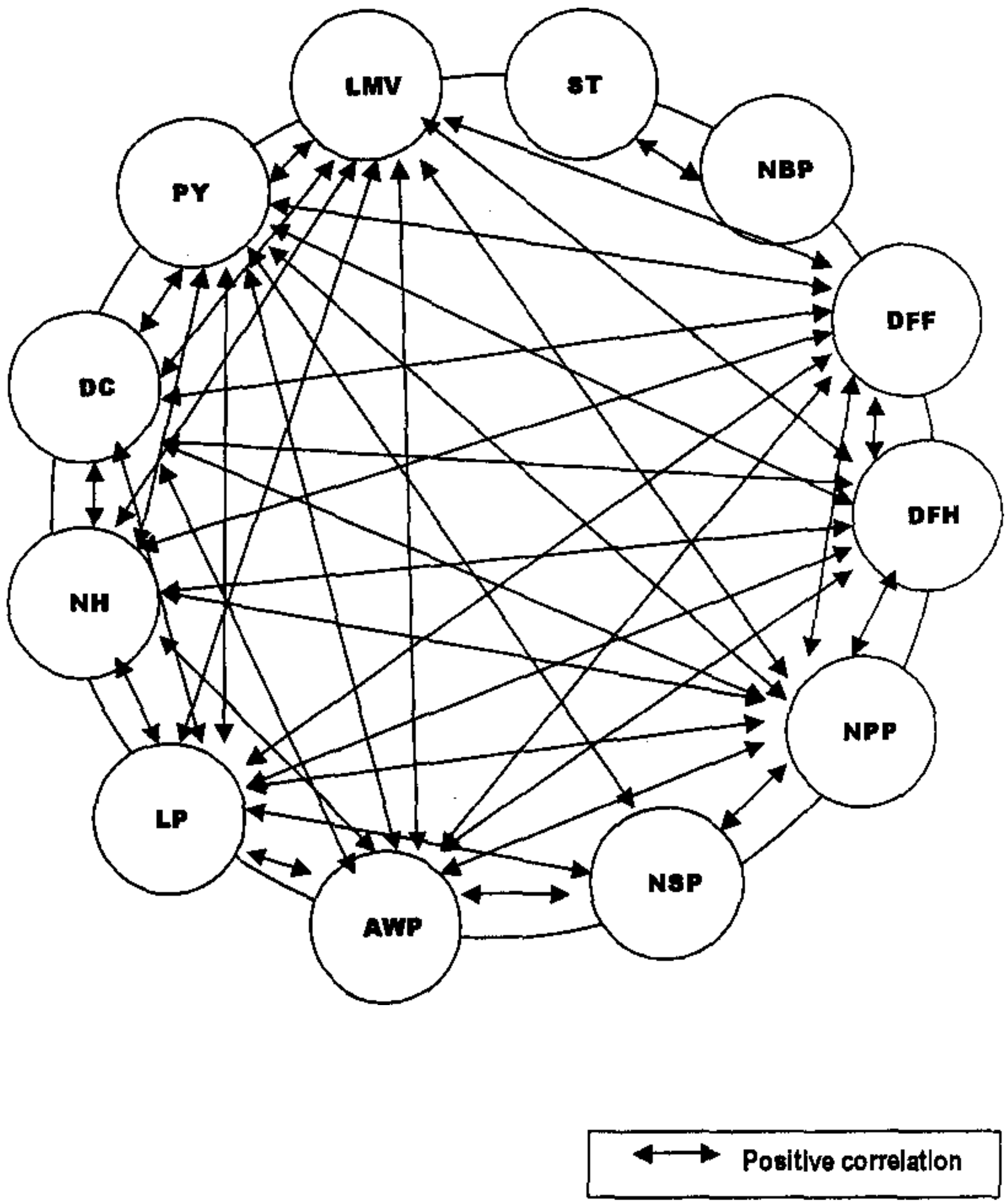

Fig. 5.2. Genotypic correlations in parents and hybrids

LMV- Length of main vine
DFF- Days for first flowering
NSP – Number of seeds/pod
NH – Number of harvests

ST- Stem thickness
DFH – Days to first harvest
AWP – Average pod weight
DC – Crop duration

NBP- Number of branches/plant
NPP – Number of pods/plant
LP – Pod length
PY – Pod yield

5.3.2 Direct and indirect effects

Path coefficient analysis is helpful in partitioning total correlation into direct and indirect effects, so that direct influences of component traits are uncompounded by other traits and their effects can be clearly understood (Fig. 5.3). Characters such as number of pods per plant, length of main vine at final harvest, average weight of pod, days to first harvesting, pod length and stem thickness exerted moderate to high positive direct effect on pod yield, with similar positive and significant genotypic correlation with yield (Table 4.3).

Although the characters like number of branches per plant, days to first flowering, number of seeds per pod and number of harvests showed positive genotypic correlation on pod yield, they had shown negative direct effect towards pod yield. Association of these characters on pod yield is interrelated among other traits. So considerations of mere inter-relationship between the traits for selection will not give fruitful selects. Trailing types give higher yield, coupled with shorter days to flowering, increased number of pods per plant, shorter days to harvest, increased duration of crop, lower seeds per pod and lower number of branches per plant. Number of pods per plant exerted the maximum positive direct effect on pod yield. The reports of Resmi (1998), Vidya and Oomen (2002) and Kutty *et al.* (2003) were in support of the above findings.

5.4 COMBINING ABILITY ANALYSIS

The combining ability analysis provides an understanding of the genetic architecture of traits, which would be useful to identify parents for heterosis breeding and handling segregating material. The ability of a parent to combine well with other parents is depends on various complex gene interactions, which cannot be realized from phenotypic values. Diallel analysis is an efficient tool for the plant breeders to estimate the genetic components of variation and combining ability of selected genotypes in a series of crosses. Full diallel technique was followed for estimating GCA, SCA variances and its effects. Additive variance is due to additive gene action, which is equal to twice GCA variance. However, if

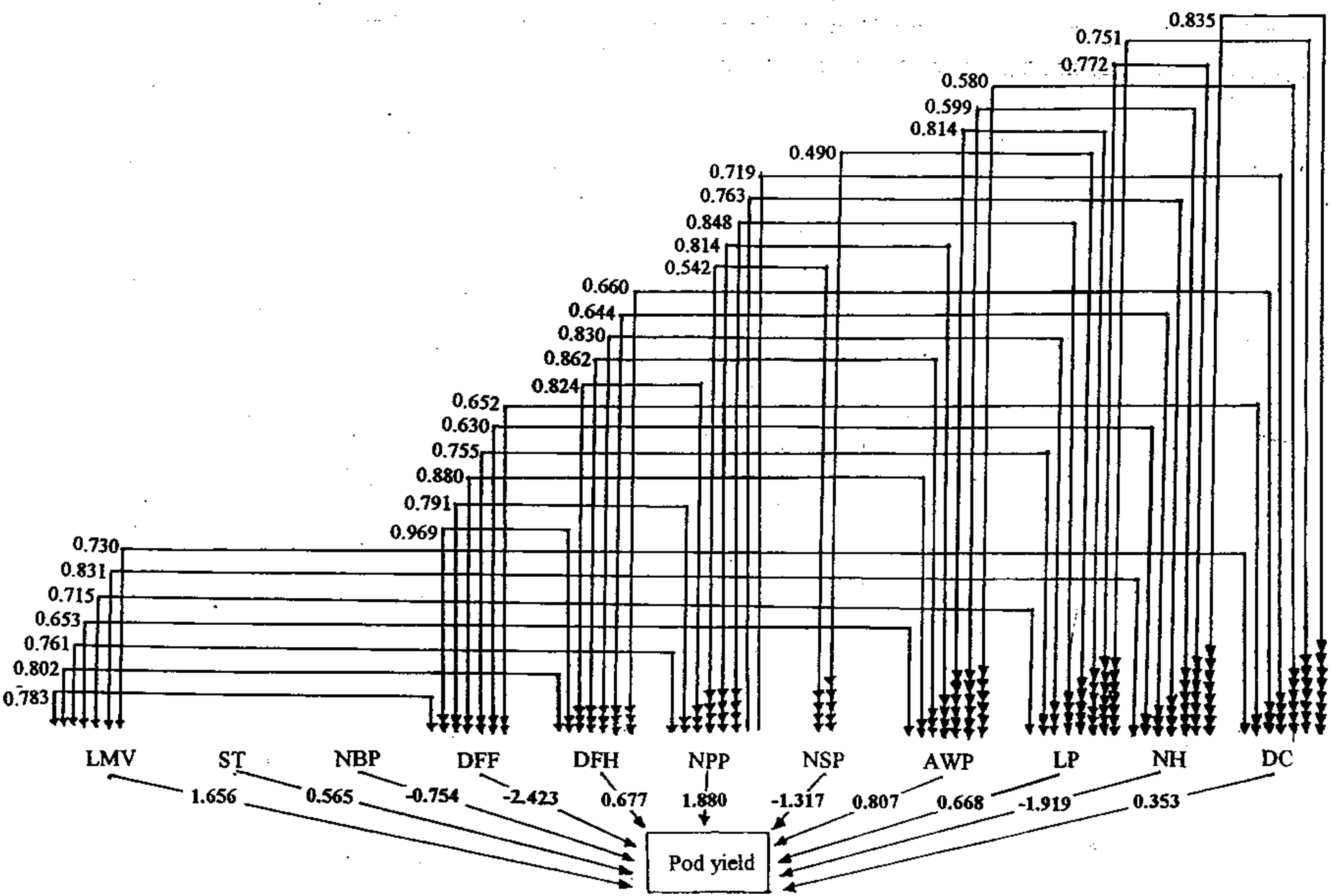

Fig. 5.3 Path diagram of parents and hybrids among yield and its component traits

LMV- Length of main vine
ST- Stem thickness
NBP- Number of branches/plant
DFF- Days for first flowering
DFH – Days to first harvest
NPP – Number of pods/plant
NSP – Number of seeds/pod
AWP – Average pod weight
LP – Pod length
NH – Number of harvests
DC – Crop duration
PY – Pod yield

epistasis is present GCA variance will include additive x additive component also. SCA variance that deals with non-additivity of genes is mainly attributable to dominance variance or it may also include other two types of epistatic interaction namely additive x dominance and dominance x dominance.

5.4.1 Combining ability variance

ANOVA for combining ability showed significance *gca* effects for all the characters studied and *sca* effects for 11 characters, thereby indicating the importance of both additive and non-additive gene actions. This is in conformity with earlier findings of Patel *et al.* (1994), Sobha *et al.* (1998) and Valarmathi (2003). The greater magnitude of SCA variance over GCA variance for all the traits studied indicated the preponderance of non-additive gene action for these traits. *gca* effects revealed that , Lola for high yield followed by Vyjayanthi and for length of main vine, Vyjayanthi followed by Lola were the best combiners where as for bush types, TC-99-1 is the best. For reducing the days to first flowering, TC-99-1 was the best parent and for increasing the number of pods per plant Vyjayanthi was the best combiner identified. Pusa Komal can be used as a good combiner for reducing the duration of crop with better pod yield. Promising parents and hybrids identified based on combining ability is presented in Table 5.1. The overall performance of parents for different traits revealed that the improvement of pod yield with short duration and bush nature could be achieved by TC-99-1. The cross combination having significant *sca* effects indicated that Lola x Bhagyalakshmi are the best combiners for number of pods per plant, days to first flowering and number of seeds per pod and length of pod.

Vyjayanthi x Bhagyalakshmi are the best combiners for reducing the vine length, number of branches per plant, days to first flowering and harvesting and for reducing the frequency of harvesting. Pusa Komal x TC-99-1 are the best combiners for improving the average weight of pod. Perusal of the values of *sca* effects revealed that in all the crosses with higher *sca* effects either one or both the parents were good general combiners for the characters. Reports of Sobha *et al.* (1998) and Patil and Shettee (1986) supported the present findings.

Table 5.1 Promising parents and hybrids identified based on combining ability effects

Characters	Combining ability			
	gca effect		*sca* effect	
	High	Low	High	Low
Length of main vine at final harvest (cm)	Vyjayanthi	TC-99-1	$P_1 \times P_3$	$P_2 \times P_3$
Stem thickness (mm)	Pusa Komal	Bhagyalakshmi	$P_2 \times P_5$	$P_3 \times P_4$
Number of branches per plant	Lola	TC-99-1	$P_2 \times P_5$	$P_2 \times P_3$
Days to first flowering	Lola	TC-99-1	$P_1 \times P_3$	$P_2 \times P_3$
Days to first harvesting	Vyjayanthi	TC-99-1	$P_1 \times P_3$	$P_2 \times P_3$
Number of pods per plant	Vyjayanthi	TC-99-1	$P_1 \times P_3$	$P_2 \times P_3$
Number of seeds per pod	Vyjayanthi	Pusa Komal	$P_1 \times P_3$	$P_1 \times P_5$
Average weight of pod (g)	Vyjayanthi	TC-99-1	$P_4 \times P_5$	$P_1 \times P_5$
Length of pod (cm)	Lola	TC-99-1	$P_1 \times P_3$	$P_2 \times P_3$
Number of harvests	Vyjayanthi	TC-99-1	$P_3 \times P_5$	$P_2 \times P_3$
Duration of crop (days)	Vyjayanthi	Pusa Komal	$P_4 \times P_5$	$P_1 \times P_5$
Pod yield (g)	Lola	TC-99-1	$P_4 \times P_5$	$P_1 \times P_4$

5.5 HETEROSIS

To asses the heterotic vigour among the hybrids, heterobeltiosis, standard heterosis and relative heterosis were estimated for all the traits. Positive and negative heterobeltiosis, standard heterosis and relative heterosis were recorded for all the traits. Similar observations were made by Hazra *et al.* (1993) and Singh *et al.* (1986). Many hybrids superior performed the check variety (Vyjayanthi) for different traits. The cross combinations Lola x Vyjayanthi showed a negative trend for all the heterosis estimation indicating that segregation of this cross will give plants with shorter vine length with thick stem, shorter days to flowering, shorter duration and appreciably no reduction in number of pods per plant, number of harvests and higher yield. Supreme hybrids identified for yield and yield related characters are given in Plate 3.

Two bush type parents Pusa Komal and TC-99-1 expressed no reduction in length of main vine but more stem thickness, increased number of branches in standard heterosis. It exhibited increased seeds per pod, increased length of pod and higher pod yield in three types of heterosis. The hybrid Lola x TC-99-1 expressed good heterosis for main vine length, days to first flowering, days to first harvesting, number of pods per plant, length of the pod and duration of crop. The cross combination Vyjayanthi x Pusa Komal exhibited less number of branches per plant with a good number of pods per plant and seeds per pod. In case of Pusa Komal x TC-99-1, no heterosis was not observed in length of main vine indicating that some genes have dominance in one direction, so there will be no heterosis due to the mutual cancellation effects of such genes.

These results indicated that the crosses of extreme types like trailing x bush and cross of similar types like bush x bush and trailing x trailing can give segregants having intermixing of different traits present in both trailing and bush types. Similar observations were reported by Valarmathi (2003). The heterosis will be greatest when some alleles are fixed in one parent and other alleles in the other parent.

Vyjayanthi x Bhagyalakshmi

Pusa Komal x TC-99-1

TC-99-1 x Pusa Komal

Plate 3. Supreme hybrids for yield and yield related characters

Continued

Bhagyalakshmi x TC-99-1

TC-99-1 x Vyjayanthi

TC-99-1 x Lola

5.6 INBREEDING DEPRESSION

Inbreeding depression is an estimate of the decrease in vigour due to inbreeding. The inbreeding depression is represented by Inbreeding coefficient, which is due to fixation of unfavorable recessive genes in F_2. The estimates of heterosis and inbreeding depression together provide information about the type of gene action involved in the expression of various traits. In the case of hybrid Vyjayanthi x Bhagyalakshmi, good heterosis was observed for length of main vine at final harvest followed by good inbreeding depression indicating the presence of non-additive gene action. So this character cannot be fixed in next generations since the effects are mainly due to dominance and epistasis. Similar trend was observed in Lola x Bhagyalakshmi also. Lola x Vyjayanthi recorded negative standard heterosis for length of main vine. The cross also depicted good inbreeding depression, which shows non-fixation of reduced length of main vine in succeeding generations. In case of number of branches per plant, Vyjayanthi x Bhagyalakshmi recorded less number of branches per plant with low inbreeding depression indicating that this character can be fixed in next generations since additive gene action is important. Lola x Pusa Komal recorded high heterosis for pod yield with low inbreeding depression, showing that this character can be fixed in next generations and scope for segregants with good pod yield can be obtained. Vyjayanthi x TC-99-1 exhibited similar trend for length of the pod and number of pods per plant.

Promising F_2 segregants with desirable characters were noticed and are given in Plate 4.

5.7 SEGREGATION PATTERN OF CHARACTERS

The inheritance pattern of plant habit, flower colour, pod colour, stem colour and seed coat colour were studied for twenty crosses through chi-square test of goodness of fit.

The genotypes having the extreme characters, trailing and non-trailing were crossed, the F_1 will express the middle value of the parental characters and

Pusa Komal x Lola

Vyjayanthi x TC-99-1

Pusa Komal x TC-99-1

Plate 4. Promising F_2 segregants

continued

Bhagyalakshmi x Lola

TC-99-1 x Vyjayanthi

the F_2 segregants will produce a varied spectrum of height combinations for the above characters. This is evident in this study also. Apparently, we can say that trailing habit in cowpea is a quantitative character and hence it is controlled by more than one gene (Amma, 1981). However, if we assess the trailing nature and bushy nature as quantitative units, the segregating population can still be fit into the ratio 3:1 (trailing: bushy), as trailing nature is dominant over bushy nature.

For flower colour, the inheritance studies showed that purple colour flower is completely dominant over white. A monogenic segregation pattern 3:1 for purple to white flowers observed in this study. Similar trend for flower colour was observed by Venugopal and Goud (1996) and Valarmathi (2003) in cowpea. One purple allele when present, the colour of the flower will be always purple. Genes for white will express only in the absence of dominant purple alleles. Recessive alleles of the purple can express only in the absence of white dominant alleles. If all genes are in the recessive, then purple will be expressed. Nevertheless, the same trend was not exhibited in all the crosses. The deviation from above conclusion was occurred only in one cross that was white x white, which produces purple F_1 s and F_2 s, and this aspect needs further study.

For pod colour a monohybrid ratio of 3:1 (purple: green) was observed in most of the cases. Valarmathi (2003) reported a monohybrid ratio of 3:1 (purple: green) for pod colour. The cross Bhagyalakshmi x Lola produced purple pods in F_1 and F_2 generations where as both the parents had green pods, which again needs further study.

A dihybrid ratio of 9:7 for purple and green stems was observed for the present study. The probable dihybrid ratio 9:7 can fit in the segregating populations with predominance of complementary gene action. The production of either purplish or green stem phenotypes requires the presence of dominant alleles of both the genes controlling the trait. When anyone of the two or both the genes are present in the homozygous recessive state, the contrasting phenotype is produced. Karkanavar *et al.* (1991) and Valarmathi (2003) observed same dihybrid ratio for stem colour.

For seed coat colour, a segregation pattern 12:3:1 was observed in 14 crosses among 20 crosses studied. Thus seed coat colour in cowpea was influenced by dominant epistatic gene action. In this interaction, the two genes affecting a single character produced distinct phenotypes when they were alone. But when both the genes were present together, the expression of one gene masked *the expression of the other. Neema (1996) reported similar type of segregation* pattern for seed coat colour. The study also revealed that black seed coat colour is dominant over all the colours.

Summary

6. SUMMARY

The present investigation of 'Genetics of trailing habit in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)' envisaged identifying potential parents and superior cross combinations of trailing and bush types, thereby to get an insight about the genetics of the above traits. The study consists of five cowpea genotypes (two trailing varieties and three bush types). The following salient findings were elucidated.

- The five parental genotypes showed significant differences for all the traits studied. The 20 hybrids evolved also showed the same trend.
- Pod yield, length of pod, days to first flowering, days to first harvesting and number of pods per plant were mainly influenced by allelic contribution, where as number of harvest, stem thickness and number of branches per plant were influenced by both environment and alleles.
- Greater magnitude of variability was noted for length of main vine at final harvest and number of branches per plant.
- Length of main vine at final harvest, duration of crop and pod yield showed both high heritability and genetic advance indicating selection might be effective for crop improvement.
- The characters like length of main vine at final harvest, number of branches per plant, days to first flowering, days to first harvesting, number of pods per plant, number of seeds per pod, average weight of pod, length of the pod, number of harvests and duration of crop had significant genotypic association with yield revealing that pod yield can be increased by selecting the genotypes based on the above traits.
- Direct and indirect effect studies indicated that number of pods per plant and main vine length exerted positive direct effect on pod yield. Crop yield can be improved through direct selection considering the above characters.
- Pod yield can be increased by selecting genotypes having shorter days to flowering, increased number of pods per plant, shorter days to harvest,

increased duration of crop, lower seeds per pod, lower number of branches per plant and higher number of pods.

- Both *gca* and *sca* effects have significant importance indicating additive and non-additive gene action operating in the expression of all the traits studied, however SCA variance has greater magnitude over GCA variance showing the preponderance of non-additive gene action for the traits studied.
- Trailing type Lola has higher breeding value (*gca* effects) compared to Vyjayanthi where as TC-99-1 can be used for reducing days to flowering in a hybridization programme. TC-99-1 can be used as the best combiner for short duration, bush nature and better pod yield, where as Vyjayanthi and Bhagyalakshmi cross combination can be used for reducing the duration of crop.
- For exploiting the heterotic vigour, hybrid Lola x TC-99-1 can be used for many of the important traits like length of the main vine at final harvest, days to first flowering, days to first harvesting, number of pods, length of pod and duration of crop.
- Hybridizing extreme types like trailing x bush and vice versa can yield segregants having cross combination of different traits. The selection of the segregants can give genotypes having characters of both bush and trailing types.
- Inbreeding depression studies indicated that fewer numbers of branches per plant could be fixed in the segregating generations. Hybridization between Lola and Pusa Komal can give higher pod yield and due to low inbreeding depression, this character can easily be fixed in segregating generations.
- The segregation for plant type (trailing:bush) showed a 3:1 ratio. For stem pigmentation a dihybrid ratio of 9:7 (purplish:green) was obtained in the F_2 segregating generation for different cross combinations.
- For flower colour, a monogenic segregating pattern 3:1 (purple to white) and for pod colour, 3:1 ratio (purple to green) was obtained.

- The segregation for seed coat colour in F_2 showed a segregating ratio 12:3:1 indicating the dominant epistatic gene action.

References

REFERENCES

Ajith, P.M. 2001. Variability and path analysis in bush type vegetable cowpea (*Vigna unguiculata)*. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 128 p

Amma, S.B. 1981. Investigations on intervarietal F_2 hybrids in cowpea. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 108 p

Anbuselvum, Y., Manivannan, N., Murugan, S., Thangavelu, P. and Ganesan, J. 2000. Variability studies in cowpea (*Vigna unguiculata* (L.) Walp.). *Legume Res.* 23(4): 279-280

Aravindhan, S. and Das, L.D.V. 1996. Heterosis and combining ability in fodder cowpea for green fodder and seed yield. *Madras agric. J.* 83(10): 11-14

Baskaraiah, K.B., Shivasankar, G. and Virupakshappa, K. 1980. Hybrid vigour in cowpea. *Indian J. Genet. Pl. Breeding* 40: 334-337

Bastian, D., Das, L.D.V., Kandasamy, G. and Sakila, M. 2001. Path analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras agric J.* 88(7-9): 526-527

Baudoin, J.P. and Marechal, R. 1985. Genetic diversity in *Vigna*. *Cowpea: Research, Production and Utilization* (eds. Singh, S.R. and Rachie, K.O.). John Wiley and Sons, New York, pp. 3-9

Bhushana, H.O., Viswanatha, K.P., Manjunatha, A., Kulkarni, R.S. and Khyad, P.R. 1998. Combining ability for seed yield and its components in cowpea (*Vigna unguiculata* (L.) Walp.). *Crop Improv.* 25(2): 116-118

Bhushana, H.O., Viswanatha, K.P. and Arunachalam P. and Halesh, G.K. 2000. Heterosis in cowpea. *Crop Res.* 19(2): 277-280

Bhuvaneswari, A. 2001. Studies on inheritance of quanlitative and quantitative characters in lablab bean (*Lablab purpureus* var. *typicus*). M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, 130 p

Borah, H.K. and Khan, F.A.K. 2000. Variability, heritability and genetic advance in fodder cowpea. *Madras agric. J.* 87(1-3): 165-166

Chattopadhyay, A., Dasguptha, T., Hazra, P. and Som, M.G. 1997. Estimation of genetic parameters in parental, F_1 and F_2 generations of cowpea (*Vigna unguiculata* (L.) Walp.). *Indian Agricst* 41(1): 49-53

*Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* 51(9): 515-518

Dhillion, B.S. 1975. The application of partial diallel crosses in plant breeding-a review. *Crop Improv.* 21(2): 1-8

*Feng, W.Y., Zhang, W.Z. and Diming, G. 1997. Agronomic character analysis of yard long bean genetic resources. *China Vegetables* 2: 15-18

Fery, R.L. 1985. The genetics of cowpeas - a review of the world literature. *Cowpea: Research, Production and Utilization* (eds. Singh, S.R. and Rachie, K.O.). John Wiley and Sons, New York, pp. 25-62

*Griffing, J. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Aus. J. Bio. Sci.* 9: 463-493

Hanson, C.H., Robinson, H.F. and Comstock, R.E. 1956. Biometrical studies of yield in segregating populations of Korean lespedeza. *Agron. J.* 48: 268-272

Hazra, P., Das, P.K. and Som, M.G. 1993. Analysis of heterosis for pod yield and its components in relation to genetic divergence of the parents and specific combining ability of the crosses in cowpea (*Vigna unguiculata* (L.) Walp.). *Indian J. Genet.* 53: 418-423

Inasi, K.A. 1980. Genetic studies in cowpea. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 136 p

Jalajakumari, M.B. 1981. Variability studies in cowpea. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 138 p

Jayarani, L.S. and Manju, P. 1996. Combining ability in grain cowpea. *J. trop. Agric.* 34(2): 93-95

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Genotypic and phenotypic correlation in soybean and their implication in selection. *Agron. J.* 47: 477-483

Joshi, S.S., Sreekantaradhya, R., Shambulingappa, K.G., Jangannatha, D.P. and Jayaram, C.V. 1994. Inheritance of a few qualitative characters in cowpea (*Vigna unguiculata* (L.) Walp.). *Crop Res.* 8(2): 330-336

Jyothi, C. 2001. *Genetics of bruchid (Callosobruchus sp.) resistance* and yield in cowpea. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 128 p

Kalaiyarasi, R. and Palanisamy, G.A. 2000. Estimation of genetic parameters in five F_4 populations of cowpea. *Ann. agric. Res.* 21(1): 100-103

Kapila, R.K., Gupta, V.P. and Rathore, P.K. 1994. Combining ability over locations for seed yield and other quantitative traits in soyabean. *Indian J. agric. Res.* 28: 245-250

Karkannavar, J.C., Venugopal, R. and Goud, V.J. 1991. Inheritance and linkage studies in cowpea. *Indian J. Genet.* 51(2): 203-207

Kerala Agricultural University. 2002. *Package of Practices Recommendations: Crops.* 12th edition. Kerala Agricultural University, Thrichur, 278 p

Kutty, N.C., Mili, R and Jaikumaran, U. 2003. Correlation and path coefficient analysis in vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *Indian J. Hort.* 60(3): 257-261

Lodhi, G.P., Jain, B.S. and Chand, B. 1990. Heterosis for fodder yield and quality characters in cowpea (*Vigna unguiculata* (L.) Walp.). *Crop Res.* 3: 66-73

Madhusudan, K., Ramesh, S., Rao, A.M., Kulkarni, R.S. and Savithramma, D.L. 1995. Combining ability in cowpea. *Crop Improv.* 22(2): 241-243

Malarvizhi, D. and Rangasamy, P. 2003. Character association and component analysis in F_2 generation of cowpea (*Vigna unguiculata* (L.) Walp.). *Legume Res.* 26(4): 264-267

Mylswami, V. 1988. A general study through D^2 analysis, line x tester and triple test cross analysis in cowpea, *Vigna unguiculata* (L.) Walp. Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, 230 p

Nagaraj, K.M., Savithramma, D.L. and Ramesh, S. 2002. Triple test cross analysis in two crosses of vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *South Indian Hort:* 50: 98-104

Neema, V.P. 1996. Genetic analysis in cowpea (*Vigna unguiculata* (L.) Walp.). Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, 226 p

Parihar, M.S., Saraf, P.K., Tiwari, J.P. and Upadhyay, P.C. 1997. Correlation of growth and yield parameters with seed yield under varying plant densities and fertilizer doses in cowpea (*Vigna unguiculata* L.Walp.). *Orissa J. Hort.* 25(1): 73-75

Patel, R.N., Godhani, P.R. and Fougat, R.S. 1994. Combining ability in cowpea (*Vigna unguiculata* (L.) Walp.). *Gujarat agric. Univ. Res. J.* 20(1): 70-74

Pathmanathan, U., Ariyanayagam, R.P. and Haque, S.O. 1997. Genetic analysis of yield and its components in vegetable cowpea *(Vigna unguiculata* (L.) Walp.). *Euphytica* 96(2): 207-213

Patil, R.B. and Shetec, M.M. 1986. Combining ability analysis in cowpea. *J. Maharastra agric. Univ.* 12: 51-54

Pournami, R.P. 2000. Evaluation of vegetable cowpea (*Vigna unguiculata* sub sp. *sesquipedalis* (L.) Verdcourt) for legume pod borer, *Maruca vitriata* (Fab.) resistance and yield. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 160 p

Premsekar, S. and Raman, V.S. 1972. A genetic analysis of the progenies of the hybrid *Vigna sinensis* (L.) savi and *Vigna sesquipedalis* (L.) Frun. *Madras agric. J.* 159: 449-456

Rajaravindran, R. and Das, L.D.V. 1997. Variability, heritability and genetic advance in vegetable cowpea. *Madras agic. J.* 84(11/12): 702-703

Rajkumar, S. Singh, P. and Joshi, A.K. 1999. Heterosis in cowpea. *Veg. Sci.* 26(1): 22-26

Ram, D. and Singh, K.P. 1997. Variation and character association studies in cowpea (*Vigna unguiculata* (L.) Walp.). *Hort. J.* 10: (2) 93-99

Rangaiah, R. and Mahadevu, P. 1999. Genetic variability, correlation and path coefficient analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras agric. J.* 86(7-9): 281-284

Rejatha, V. 1992. Combining ability in vegetable cowpea *(Vigna unguiculata var. sesquipedalis)*. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 113p

Resmi, P.S. 1998. Genetic variability in yard long bean ((*Vigna unguiculata* sub sp. *sesquipedalis* (L.) Verdcourt). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 125 p

Rewale, A.P., Birari, S.P. and Jamadagni, B.M. 1995. Genetic variability and heritability in cowpea. *Agric. Sci. Digest.* 15(2): 73-76

Robinson, H.F., Comstock, R.E. and Harvey, P.H. 1951. Genotypic and phenotypic correlation in corn and their implication in selection. *Agron. J.* 43: 282-287

Sangwan, R.S. and Lodhi, G.P. 1995. Heterosis for grain characters in cowpea *(Vigna unguiculata* (L.) Walp.). *Legume Res.* 18(2): 75-80

Satishkumar, P. 2000. Study on genetic relationship between grain and vegetable cowpea (*Vigna unguiculata* (L.) Walp.) hybrids based on combining ability, component and RAPD analysis. M.Sc. (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, 120 p

Selvalakshmi, B. 1995. Heterosis and combining ability in cowpea (*V. unguiculata* (L.) Walp.). M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, 178p

Shanmugasundaram, P. and Rangasamy, S. 1994. Combining ability for yield and its components in black gram (*Vigna mungo* (L.) Hepper). *Indian J. Genet.* 54: 6-9

Sharma, P.P. and Joshi, A.K. 1993. Improvement of cowpea. *Advances in Horticulture: 5. Vegetable crops, Part I* (eds. Chandha, K.L. and Kalloo, G.). Malhotra Publishing House, New Delhi, pp. 255-275

Sharma, T.R. 1999. Genetic variability studies in cowpea. *Legume Res.* 22(1): *65-66*

Shashibushan, D. and Chaudari F.P. 2000. Heterotic studies in cowpea. *Ann. agric. Res.* 21(2): 248-252

Singh, B.B., Chambliss, O.L. and Sharma, B. 1997. Recent advances in cowpea breeding. *Crop Sci.* 30: 879-881

Singh, N., Singh, V.P., Singh, J.V. and Singh, N. 1998. Correlation and path coefficient analysis in cowpea *(Vigna unguiculata* L.Walp.). *Forage Res.* 24(3): 139-141

Singh, R., Singh, S. and Paroda, R.S. 1986. A study of heterosis, heritability and genetic advance in cowpea. *Forage Res.* 12(1): 43-47

Singh, R.P. 1983. Heterosis in cowpea. *J. Res. Assam agric. Univ.* 4(1): 12-14

Sivasubramanian, S. and Menon, M. 1973. Heterosis and inbreeding depression in rice. *Madras agric. J. 60: 1139-1144*

Smitha, S. 1995. Gene action and combining ability in grain cowpea (*Vigna unguiculata* (L.) Walp.) in relation to aphid borne mosaic virus resistance. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 135 p

Sobha, P.P. 1994. Variability and heterosis in bush type vegetable cowpea (*Vigna unguiculata* L. Walp.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 119 p

Sobha, P.P., Vahab, M.A. and Krishnan, S. 1998. Combining ability analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *J. tropic. Agric.* 36: 24-27

*Sprague, C.F. and Tatum.L.A. 1942. General versus specific combining ability in single crosses of corn. *J. Am. Soc. Agron.* 34: 923-932

Subbiah, A., Anbu, S., Selvi., B. and Rajankam, J. 2003. Studies on the cause and effect relationship among the quantitative traits of vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *Legume Res.* ,26(10): 32-35

Talukdar, T. and Talukdar, D. 2003. Inheritance of growth habit and leaf shape in mungbean *(Vigna radiata* (L.) Wilezek.). *Indian J.Genet.* 63(2): 165-16

Thiyagarajan, K., Natarajan, C., Rathinaswamy, R. and Rajasekheran, S. 1993. Combining ability for yield and its components in cowpea. *Madras agric. J.* 80(3): 124-129

Tiwari, D.S., Singh, V. and Shukla, D.S. 1993. Combining ability studies in mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Genet.* 53: 395-398

Tyagi, P.C., Kumar, N. and Agarwal, M.C. 2000. Genetic variability and association of component characters for seed yield in cowpea (*Vigna unguiculata* (L.) Walp.). *Legume Res.* 23(2): 92-96

Uguru, M.I. and Uzo, J.O. 1991. Segregation pattern of decumbent, climbing and bushy growth habits in *Vigna unguiculata*. *Pl. Breeding* 107: 173-176

Valarmathi, G. 2003. Genetic analysis in intersubspecies crosses of cowpea *(Vigna unguiculata* ssp. *unguiculata* and *Vigna unguiculata* ssp. *sesquipedalis).* Ph.D thesis, Tamil Nadu Agricultural University, Coimbatore, 245 p

Vardhan, P.N.H and Savithramma, D.L. 1998. Variability character association, path analysis and assessment of quality parameters in cowpea *(Vigna unguiculata)* germplasm for vegetable traits. *ACIAR Fd Legume Newsl.* 28: 7-8

Venkatesan, M., Prakash, M. and Ganesan, J. 2003. Correlation and path analysis in cowpea *(Vigna unguiculata* L.). *Legume Res.* 26(2): 105-108

Venugopal, R. and Goud, J.V. 1996. Inheritance in cowpea *(Vigna unguiculata* (L.) Walp.*)* floral characters. *Mysore J. agric. Sci.* 30(1): 14-20

Vidya, C. 2000. Legume pod borer resistance and genetic divergence in domestic germplasm of yard long bean.(*Vigna unguiculata ssp. sesquipedalis* (L.) Verdc.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 125 p

Vidya, C. and Oommen, S.K. 2002a. Correlation and path analysis in yard long bean. *J. trop. Agric.* 40: 48-50

Vidya, C., Oomen, S.K. and Kumar, V. 2002b. Genetic variability and heritability of yield and related characters in yard long bean. *J. trop. Agric.* 40: 11-13

* Original not seen

GENETICS OF TRAILING HABIT IN YARD LONG BEAN
(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)

By

ANISHA GEORGE

ABSTRACT OF THE THESIS

submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

(PLANT BREEDING AND GENETICS)

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2004

ABSTRACT

A study has been undertaken in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, to investigate the 'Genetics of trailing habit in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)' and to identify the potential parents and superior cross combinations of trailing and bush types cowpea during 2002-04.

Two trailing varieties and three bush varieties were used for study. The study revealed that pod yield, length of pod, number of pods per plant, days for first flowering and first harvesting were mainly influenced by allelic contribution where as duration of crop and pod yield can be used as selection parameters of crop improvement. Pod yield can be increased by selecting the genotypes having shorter days for first flowering and harvesting, increased number of pods per plant, lower number of seeds per pod, lower number of branches and higher number of pods. Trailing type, Lola has higher breeding value compared to Vyjayanthi and TC-99-1 and can be exploited for heterotic vigour for many of the yield attributes. The segregants can be used for fixing characters of both bush type coupled with trailing traits. Segregants of Lola x Pusa Komal can give higher pod yield and the yield attributes can be easily fixed in the segregating generations due to its low inbreeding depression. Trailing and bush characters showed a 3:1 monohybrid ratio and stem pigmentation (purplish: green) showed a dihybrid ratio of 9:7 in the F_2 segregants of different combinations. Flower colour (purple: white) and pod colour (purple: green) showed a monogenic segregation ratio of 3:1 where as seed coat colour showed dominant epistatic gene action (12:3:1) in various crosses. Segregants can be further screened for higher pod yield coupled with tolerance to biotic and abiotic stresses, which is indicated as future line of work.