GENETIC ANALYSIS OF YIELD AND FUSARIUM WILT RESISTANCE IN LINE × TESTER PROGENY OF YARD LONG BEAN

(*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)

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DECLARATION

I hereby declare that this thesis entitled "**Genetic analysis of yield and fusarium wilt resistance in line × tester progeny of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Genetic analysis of yield and fusarium wilt resistance in line × tester progeny of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)**" is a record of research work done independently by Ms. Renjana, G. Nair (2004-11-42) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	per cent
σ^2A	Additive variance
σ^2D	Dominance variance
µg	Micro gram
^0C	Degree Celsius
ANOVA	Analysis of variance
CD	Critical difference
cm	Centimetre(s)
et al.	And others
F_1	First filial generation
Fig.	Figure
g	Gram(s)
GCA	General combining ability variance
gca	General combining ability effect
i.e.	That is
KAU	Kerala Agricultural University
kg	Kilogram
L x T	Line x Tester
m	Metre
M	Molar
mg	Milligram
ml	Millilitre
mm	Millimeter
MSE	Error mean square
Na2CO3	Sodium carbonate
nm	Nanometre
NS	Non significant
PDA	Potato Dextrose Agar
ppo	Polyphenol oxidase

LIST OF ABBREVIATIONS continued

PVP	Polyvinyl pyrrolidone
RBD	Randomised Block Design
rpm	Revolutions per minute
SCA	Specific combining ability variance
sca	Specific combining ability effect
SE	Standard error
SS	Sum of squares
UV VIS	Ultraviolet visible
viz.	Namely

Introduction

1. INTRODUCTION

The yard long bean, *Vigna unguiculata* sub sp. *sesquipedalis* (L.) Verdc. (Syn. String bean, asparagus bean, sitao and snake bean) is a common leguminous vegetable crop grown throughout the world. In India, this crop is cultivated in an area of about 7.7 million ha. Among the South Indian states, Kerala has the most extensive cultivation. Africa is considered as the primary centre of origin (Peter, 1998). It is a true diploid (2n=22) self pollinated species. The long tender pods are rich in protein, minerals, vitamins, dietary fibre and are highly nutritious.

The productivity of this crop is low (3q/ha) which needs improvement through systematic breeding programmes (Yadav *et al.*, 2004). The breeder of vegetable cowpea aims at the production of high yielding good quality green pods. Choice of best parents is a pre-requisite in all crop breeding programmes. Evaluation of parents for their transmission potential for yield and yield components will gave a way for better selection. All available parents with high order of performance may not be able to transmit their superior traits to their progenies. Hence selection of desirable parents based on their combining ability is increasingly used now a days in crop improvement programmes. Combining ability analysis also furnishes the nature and magnitude of gene action involved. It helps in framing a suitable breeding scheme for the amelioration of characters under consideration. Among the different methods of crop improvement programme, Line x Tester analysis is an important mating system enjoying universal application in Plant Breeding. Because of its simplicity in both experiment and analysis, this technique is adopted in the present study. Such studies are useful in assessing heterosis

for identifying promising crosses in early generation, that can give transgressive segregants in later segregating generations.

Incidence of pests and diseases is a major bottleneck in the cultivation of legumes. Crop losses due to wilt disease especially those caused by *Fusarium oxysporum* continue to be a limiting factor in maximising yield in vegetables especially in cowpea. Developing varieties resistant to this soil borne disease would continue to play an important role, for the simple reason that this is cheap and best method of disease management. Although high resistance may not be attainable, even moderate resistance may help to make other measures more effective. Hence this work is intended to identify the sources of resistance against Fusarium wilt and also for developing high yielding varieties of yard long bean.

Keeping in view the above mentioned aspects, the present investigation was undertaken with the following objectives:

- To study the combining ability variances and nature of gene action involved in inheritance of various characters.
- To study the magnitude of heterosis of crosses for quantitative and biochemical characters.
- To identify yard long bean genotypes resistant to Fusarium wilt disease.

Review of Literature

2. REVIEW OF LITERATURE

The present study involved evaluation of domestic germplasm of yard long bean for vegetable pod yield and Fusarium wilt resistance. Despite its wide genetic variability, nutritional and economic importance, very little attention has been paid to the improvement of this crop. Crop improvement works appear to be scanty in yard long bean. However relevant literature available on crop improvement in cowpea in general is reviewed here under

2.1 L x T ANALYSIS

Line x tester analysis is an important mating system enjoying universal application in Plant Breeding, because of its simplicity in both experiment and analysis. Such studies are useful in assessing heterosis for identifying promising crosses in early generation, that can give transgressive segregants in later segregating generations.

Mishra *et al.* (1987) indicated the importance of both gca and sca for days to 50 per cent flowering in line x tester analysis involving four testers and ten lines of cowpea.

Combining ability studies of 25 chickpea hybrids derived from crosses of five lines and five testers with their F_2 and parents by Bahl and Kumar (1989) revealed that estimates of sca were greater than gca for almost all quantitative traits studied.

In a line x tester analysis of cowpea, Thiyagarajan (1990) observed the preponderance of additive variances for number of seeds per pod.

A line x tester analysis to estimate the combining ability of cowpea varieties revealed the predominance of non-additive gene action for number of pods per plant (Kumar, 1993).

Based on line x tester analysis in cowpea (Madhusuda *et al.*, 1995) good general combiners for pod yield and seed yield per plant were identified

and both additive and non-additive genetic variances were found important in the inheritance of quantitative traits with a preponderance of non-additive gene effects in most cases.

Varghese (1997) in a L x T analysis in blackgram observed significance of gca and sca variances indicating the influence of both additive and non-additive gene action for pods per plant. But non additive gene action seems to be predominant since the ratio of additive to dominance variance was less than unity.

In a line x tester study, the total genetic variation in pigeon pea was due to overdominance and non-additive type of gene action was noticed for days to flowering, plant height, number of primary and secondary branches per plant, clusters per plant, pods per plant and seed yield per plant and partial dominance of additive gene action for days to maturity (Pandey and Upadhyay, 1999).

A line x tester analysis of combining ability by Ramalingam and Francies (1999) reported the predominance of non-additive gene action for number of pegs, number of pods and pod yield in groundnut.

Bhushana *et al* (2000) studied heterosis in 36 hybrids produced through line x tester mating designs and it showed maximum heterosis over mid parental value for number of pods per plant. Significant positive heterosis was observed for seed yield per plant, number of primary branches per plant, pod length and test weight. Significant negative heterosis was observed for days to 50 per cent flowering in cowpea.

Jeena and Arora (2001) reported the predominance of non-additive gene action for pods per plant, yield per plant, plant height, 100 seed weight and days to maturity in chickpea. Equal importance of additive as well as non-additive genetic variances were revealed for seeds per pod and primary branches per plant.

A study on five lines and two testers of green gram showed that the non additive gene action was involved in controlling characters namely plant height, number of branches per plant, number of clusters per plant, number of pods per plant and seed yield per plant (Manivannan, 2002).

In a line x tester analysis in cowpea, Pal *et al.* (2002) found that ADCP-13, Red Seeded, Kala Zamal and Pusa Komal were good general combiners for days to 50 per cent flowering.

The combining ability analysis revealed that variance due to hybrids, lines, testers and line x tester interaction were significant for days to 50 per cent flowering, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, 100 seed weight and single plant yield. The ratio of additive and dominance genetic variance indicated the preponderance of non-additive type of gene action for all the traits except number of branches per plant (Anbumaralmathi *et al.*, 2004) in green gram.

Estimates of gca and sca were exhibited partial dominance of additive gene action for number of pods per plant, while for days to initial flowering, days to maturity, plant height, number of primary branches per plant, per cent pod setting, harvest index and seed yield per plant showed overdominance with non-additive genetic variance (Pandey, 2004) in pigeonpea

Philip (2004) reported significant gca effects for grain yield per plant, pods per plant, inflorescence per plant, pod length and seeds per pod in cowpea. Significant estimates of heterosis for inflorescence per plant, pods per inflorescence and grain yield was observed.

Studying heterosis in different L x T hybrids of urd bean indicated a pronounced hybrid vigour for yield and most of the yield components (Vaithyalingam, 2004).

A line x tester analysis including twelve lines and four testers in urd bean showed positive gca effects for 100 seed weight and seed yield per plant

(Singh, 2005a).Singh (2005b) studied genetic analysis and found that non-additive gene action have a major role in the expression of seed yield per plant, leaf area per plant, leaf growth rate, net assimilation rate and crop growth rate.

2.2 COMBINING ABILITY ANALYSIS

The concept of combining ability as a measure of gene action was proposed by Sprague and Tatum (1942). Combining ability is the ability of a strain to produce superior progeny on hybridization with other strains. This analysis helps in the evaluation of inbreds in terms of their genetic value and in the selection of suitable parents for hybridization. Information on nature of general combining ability and specific combining ability with respect to parents and hybrids will facilitate the breeder to plan the breeding programme effectively.

Patil and Shete (1987), from a 7 x 7 half diallel cross in cowpea revealed that the highest positive heterosis over mid parental value occurred for pod clusters per plant followed by seed yield per plant and, while that over the better parent was highest for pod clusters per plant followed by pods per plant.

A 6 x 6 diallel analysis done in vegetable cowpea by Rejatha (1992) showed significant difference in most of the characters except number of pods per plant and fruit yield per plant. Variance due to gca was significant and higher in magnitude than sca for the characters like days to flowering, mean weight of pod, length of internode and seed to pod ratio.

Jayarani (1993) observed that sca variance was predominant for all characters in grain cowpea suggesting its importance. Variance due to gca was larger than sca for days to 50 per cent flowering and length of pod. The sca variance was higher than that of gca for days to maturity, branches per plant, seeds per plant and seed yield per plant. High magnitude of sca variance for days to maturity, plant height, branches per plant, pods per plant,

seeds per pod, 100 seed weight and seed yield per plant suggested the predominance of additive gene action.

Smitha (1995) reported preponderance of non-additive gene action for seed yield per plant, pods per plant, seeds per pod and 100 seed weight in grain cowpea.

In cowpea, Sreekumar (1995) reported significant and positive standard heterosis, heterobeltiosis and relative heterosis for number of pods and grain yield per plant.

Nine varieties of cowpea were crossed in a partial diallel design for analyzing combining ability by Chaudhari *et al.* (1998). The parent, GC-940 was good general combiner for grain yield, plant height, branches per plant and pods per plant. Both additive as well as non-additive gene effects were involved in the inheritance for all characters with predominance of non-additive gene action.

The estimated component of variance of general combining ability were higher than specific combining ability for all characters except green pod yield per plant in cowpea indicating the predominance of additive gene action for characters. The cowpea varieties, Sel.2-2, IHR Sel.11, Pusa Komal and BC-244002 were good combiners for pod yield per plant (Kumar *et al.*, 1998).

Savithramma and Latha (1998) estimated heterosis in 45 hybrids produced by crossing 10 cowpea genotypes in diallel fashion without reciprocals. The best crosses for pods per plant were, RC-2 x V-37 and RC-2 x CO-VU-2.

Twenty one hybrids of vegetable cowpea were evaluated by Sawarkar *et al.* (1999) by diallel mating without reciprocals along with seven parents for combining ability analysis. Preponderance of additive type of gene action was observed for all characters. The best genotype on the basis of gca effect

and per se performance for pod yield and contributing characters was Punjab-263 followed by Arka Garima.

Dijee *et al.* (2000) studied the combining ability for yield and yield components in cowpea. The variance for general combining ability and specific combining ability showed that gene action was predominantly non-additive for all the characters studied.

Sarode *et al.* (2000) studied combining ability in chickpea and found that components of variance due to gca and sca revealed the predominance of non additive gene action for number of pods per plant and seed yield per plant.

A study involving three genetic male sterile lines and nine diverse testers of early duration pigeon pea revealed that non-additive genetic variance controlled the expression of yield per plant, primary branches per plant, pods per plant, seeds per pod, 100 seed weight and additive genetic variance governed the expression of days to 50 per cent flowering and plant height (Kumar *et al.*, 2001).

Singh and Mishra (2002) studied nature of combining ability through 10 x 10 diallel analysis in pea and observed that variance due to general and specific combining ability were highly significant for primary branches per plant, pods per plant, 100 seed weight, seed yield per plant and harvest index.

In 2003, Bhuvaneswari *et al.* studied combining ability in lablab through 5 x 5 full diallel cross and variance due to gca and sca was significant for all characters.

In a L x T analysis, Singh and Dikshit (2003) reported that the estimates of sca variance were higher than gca variance for plant height, clusters per plant, pods per plant, pod length and seed yield per plant in mung bean indicating the importance of non-additive gene effects in the expression of traits.

Singh and Sharma (2004) studied the inheritance of quantitative characters in garden pea and magnitude of dominance showed positive significance and dominance x dominance gene effects exhibited negative significance in majority of the crosses.

Combining ability studies in black gram through 6 x 6 diallel cross, revealed that both additive and non-additive gene action were important for plant height and seed yield per plant (Tangavel *et al.*, 2004).

Kandalkar (2005) reported that both additive and non-additive genetic components of variance governed the expression of seed yield, pods per plant, pod clusters per plant and plant height in pigeonpea.

Rizwana *et al.* (2006) studied combining ability in pigeon pea and components of variance due to gca and sca revealed predominance of additive gene action for yield characters.

2.3 HETEROSIS

The superiority of a hybrid in one or more characters over its parents is known as heterosis. The term heterosis was first used by Shull (1914). Existence of significant amount of dominance variance is essential for undertaking heterosis breeding programme. Even, the expression of small magnitudes of heterosis for a particular character is also very much desirable in breeding. High estimate of heterosis is a result of high genetic diversity among parents indicating the possibility of identifying high yielding transgressive segregate from hybrid population (Singh, 2002).

Bhaskaraiah *et al.* (1980) in a diallel analysis with 10 parents of cowpea reported highest average heterosis effect for yield and pods per plant. The least heterosis was seen for 100 seed weight. All the progenies of crosses between low and high yielding parents exhibited heterosis over mid parental value.

Significant heterosis was observed for pods per plant, seeds per plant, pod length, 100-seed weight and yield per plant; but plant height and days to

maturity gave lower values than the other traits in cowpea by Chikkadevaiah *et al.* (1980).

Four crosses amongst five cowpea varieties were studied for nine quantitative characters by Ningappa (1981). Heterosis over mid parental value, better parent and best parent was significant for pods per plant, pod yield per plant and number of primary branches in F_2 population. Inbreeding depression was marked for pod yield per plant.

Yield and seven yield related characters were studied in six cowpea genotypes and their fifteen possible non-reciprocal single crosses (Zaveri *et al.*, 1983) and reported that heterosis for seed yield was attributed to heterosis for number of clusters and pods per cluster.

Rao and Chopra (1989) studied heterosis and heterobeltiosis in chickpea and high heterosis and heterobeltiosis was observed for yield per plant, seed yield from secondary and tertiary branches, number of primary and secondary branches, plant height and weight, number of pods per plant and seed weight per unit volume for certain crosses.

Maximum heterosis was observed for seed yield per plant and pods per plant by Rejatha (1992) in cowpea.

With five parents and ten hybrids of cowpea, Hazra *et al.* (1993) found that frequency and level of heterosis was related more to sca than to genetic divergence of the parents.

Sawant *et al.* (1994) observed greatest positive heterosis over mid parent for seed yield per plant followed by inflorescence per plant, pods per plant, branches per plant and plant height in cowpea. A similar trend over better parent was observed except for branches per plant and plant height. Average heterosis over mid parent and better parent was greatest for seed yield per plant followed by pods per plant and inflorescence per plant.

Heterosis over the better parent ranged from 4.33 per cent for plant height to 91.52 per cent for days to maturity in cowpea (Bhor *et al.*, 1997).

Hybrids exhibiting high heterosis also showed high inbreeding depression, indicating the importance of non-additive gene action.

Viswanatha *et al.* (1998) studied heterosis and inbreeding depression for yield and yield components in three intervarietal crosses of cowpea. Significant heterosis over mid parent and better parent was observed for most of the characters studied. Crosses showing high heterosis also exhibited high inbreeding depression, indicating predominance of non-additive gene action for the traits studied.

Hooda *et al.* (1999) studied heterosis in pigeon pea hybrids and maximum standard heterosis was obtained for pods per plant (38.12 per cent).

Kumar *et al.* (1999) reported the cowpea genotypes var. 263, Se. 2-2 and Sel. 2-1 to be promising parents giving high heterosis vigour for most of the characters in various cross combinations.

Danam and Chaudhari (2000) crossed nine parents of cowpea in diallel (excluding reciprocals) to study heterosis over mid parent, better parent and standard parent for eleven characters. Maximum positive heterosis in seed yield was due to the heterosis found in yield component, mainly, pods per plant, seeds per pod, clusters per plant and branches per plant.

Heterosis was studied in green gram using L x T model and all the hybrids exhibited significant relative heterosis for seeds per pod. All the hybrids analysed were superior to mid parent, better parent and standard variety (Joseph and Kumar, 2000).

Sarode *et al.* (2000) studied heterosis and combining ability in eight genotypes of chickpea and revealed that hybrids, Phule G-89219 x Phule G-12 showed high heterosis for seed yield per plant as well as pods per plant and 100 seed weight.

Shashibushan and Chaudari (2000) reported maximum positive heterosis for seed yield per plant over mid parent, better parent and standard check in cowpea.

Study of heterosis in hybrids of mungbean indicated a pronounced hybrid vigour for yield and yield components and crosses between high x high and high x low gca parents exhibited greater heterosis (Loganathan *et al* .,2001).

Heterosis estimated over mid and better parents for seed yield and yield characters showed maximum heterosis for seed yield per plant in cluster bean (Mathur and Mathur, 2001).

In a line x tester mating design in pea, substantial amount of heterobeltiosis and relative heterosis was observed in four crosses, of which highest heterobeltiosis was observed in case of plant height and lowest for seed weight (Tyagi and Srivastava, 2001).

Haibatpure *et al.* (2003) studied heterosis for quantitative characters in cowpea. Heterosis in yield seemed to be influenced by heterosis in number of pods per plant, seeds per pod, branches per plant and test weight.

Singh and Dikshit (2003) studied heterosis in mungbean and substantial heterosis was observed for plant height, clusters per plant, pods per plant, pod length, pod weight, seed yield per plant and 100 seed weight.

2.4 FUSARIUM WILT

Fusarium wilt was first reported in cowpea from USA (Orton, 1902). In India, this disease was first recorded in cowpea by Singh and Sinha (1955). Allen (1983) reported involvement of *Fusarium solani* in dry root rot of cowpea.

Three races of the pathogen have been distinguished, *i.e.,* race 1 has been isolated from both cowpea and soybean; race 2 from some cowpea cultivars only; and race 3 from cowpea cv. Arlington, which is resistant to the other two races. Infected plants are more frequently noticed because the leaves become flaccid and chlorotic before falling prematurely. Closer examination reveals that the lower stem may be swollen before chlorosis appears, and necrotic vascular tissue in the stems and roots are seen often in more extensive form than might be expected from foliar symptoms. A rapid

wilt develops in young plant which are usually killed, but plants infected at a later stage in development may be stunted with slower progression of foliar chlorosis and wilt. Some infected plants may never show external symptoms, yet the vascular tissue may be severely disrupted and discoloured (Cook, 1978).

A study was conducted by Sajise (1988) to identify influence of cultivar, inoculum density and plant age on the incidence of Fusarium rot and stem rot in cowpea. Different levels of *F. solani* inoculum were inoculated to 5,17 and 22 days old seedlings of TVX 289-4G, VCS 6-1 and CES 42-2 cowpea cultivars. Among the cultivars tested, CES 42-2 was the most resistant. The degree of infection was not significantly affected by the different levels of inoculum used. However plant age significantly affected the percentage of infected plants. The infection was higher in 22 than in 17 days old plants and was completely suppressed in 5 day old seedlings.

Shihata *et al.*, (1989b) reported that the xylem extracts from healthy wilt-resistant plants of TVu 1560 were more toxic to the pathogen than extracts from susceptible Blackeye plants. In the susceptible cultivar the pathogen grew extensively in the xylem vessels, causing plugging and leading to severe disease symptoms. The population of *F. oxysporum* increased while the dry wt of the plant decreased in proportion to plant age. Younger plants were more susceptible to infection than older ones.

A bioassay of 22 cowpea cultivars showed the presence of seed borne fungi in eight centres of Brazil which include *Fusarium pallidoroseum* (26.9 %) and *F. oxysporum* (15.6 %). Cultivar Sempre-verde, Costela-de-vace and Moita had 90-100 per cent germination. A direct correlation was found between the total number of seed borne fungi and germination (Barros *et. al.*, 1990).

The wilt of cowpea was noticed in farmers' field in Thiruvananthapuram district of Kerala (Reghunath *et al.*, 1995). Fusarium wilt was characterized by yellowing of leaves followed by defoliation, drying of vines and root

decay. Sometimes there is also swelling of the basal part of the plant including the lower part of the stem and upper part of the tap root forming a tuber like structure which later gets disintegrated.

Schneider and Kelley (2000) studied Fusarium root rot in bean. The genetic resistance to the pathogen (*Fusarium oxysporum* f.sp. *phaseoli*) is considered quantitative and strongly influenced by environmental factors. They observed correlation coefficient between the greenhouse and field ratings and were significant for the screening of Fusarium root rot resistance.

The intensity of cowpea Fusarium wilt (*Fusarium oxysporum* f.sp. *tracheiphilum*) in 10 soil types in Pernambuco, Brazil was investigated by Assuncao *et al.* (2003) and verified significant correlations between disease associated variables and relative spore production of the pathogens in the different soils.

Eloy and Michereff (2003) reported that Fusarium wilt caused by *Fusarium oxysporum* f. sp. *tracheiphilum*, is an important cowpea disease in the Brazilian Northeast. Aiming to determine the correlation between disease severity and reduction of cowpea seed yield cultivated during two different period of time, an assay was carried out using plots artificially inoculated with the pathogen. At harvest, yield of each plot was determined from the total weight of seeds per plant. After harvest, the severity of Fusarium wilt was evaluated in all plants. No significant correlation was found between inoculum density of the pathogen that was present in the soil before planting and disease severity. Fusarium severity ranged between 3.2 and 93.3 per cent, while the yield loss ranged between 2.2 and 98.1 per cent. The model of simple linear regression, without data transformation, fitted the data in relation to Fusarium wilt severity and yield losses of both planting times, which proved the significant influence of the severity on yield loss levels.

Fusarium wilt is considered to be one of the most destructive soil borne disease of pulses. The yield loss due to Fusarium wilt vary with the stage at which the diseases occurs. Severe incidence of the disease during

early reproductive stage induce flower and pod abortion which drastically decrease the seed number and yield. Fusarium causing wilt was assessed by inoculating them on two week old cowpea seedlings. Among the different species of Fusarium, *Fusarium pallidoroseum* was found to be most virulent in causing cowpea Fusarium wilt (Senthilkumar, 2003).

2.4.1 Source for Resistance

The original sources of resistance to Fusarium wilt of cowpea were obtained by selecting surviving plants from susceptible cultivars that were grown in the field plots with high inoculum density (Orton, 1902). Since these field plots were infested with organisms in addition to *Fusarium*, often surviving plants had resistance to other soil borne pathogens such as charcol rot and root rot nematodes. In such tests all cultivars except 'Iron', 'Victor' and 'Brabham' were eliminated as possible breeding stocks. When wilt resistant plants of these varieties were crossed with susceptible plant their progenies segregated in such a manner as to indicate that the resistance was dominant.

Three races of *Fusarium oxysporum* f. sp. *tracheiphilum* have been reported. The races were differentiated as follows: Race 1 is pathogenic to plants of the cowpea cultivar Groit, but not to plants of cultivars of Epoit and Arlington; race 3 is pathogenic to plants of Red Chinese and Arlington but not to Groit (Armstrong and Armstrong, 1950; Hare, 1953).

Genetic studies were conducted using M455 (a probable derivative of the cultivar Iron, which is resistant to three races of cowpea wilt) and the cultivar brown sugar crowder (susceptible to all races) showed that resistance is conditioned by two dominant genes for each race 1, 2 and 3 (Hare, 1957).

Races of the fungus also have been distinguished on the basis of varietal susceptibility with cv. iron resistant to all three races, Arlington resistant to races 1 and 2 but killed by race 3 (also isolated from infected soybean), Groit killed by race 1 but not race 2 and Extra Early Black eye

killed by race 2 but not by race 1. Genetic resistance from cv. Iron has been found to result from a single dominant factor for race 1 of the causal fungus and two dominant factors each for races 2 and 3. Satisfactory control has been achieved (in the United States) through use of resistant varieties, viz. Brown sugar Crowder S-1, Grant and Missisippi Crowder (Cook, 1978).

Four varieties of cowpea were evaluated for susceptibility to *F. oxysporum* which was isolated from naturally diseased cowpea varieties by Shihata *et al.* (1988).The study indicated that varieties Black eye TVu 1330 and TVx 3236-01G were susceptible whereas the TVu 1560 was resistant.

Shihata and Gad-El-Hak (1989) observed that *Fusarium oxysporum* was the most frequent isolate from diseased plants in all the cowpea fields in Egypt . But *F. solani* and *F. moniliforme* were also present. Each fungus showed considerable pathogenic variation among different isolates and the various cultivars differed in their reaction to a highly virulent isolate of each pathogen. TVu 1560 was the most resistant to all three *Fusarium spp.* In a field trial,seed yield was significantly affected by inoculum with *F. oxysporum.* California Black eye 5 and TVu 1560 gave the highest and lowest yield reductions respectively in both seasons.

The population of *F. oxysporum* in the susceptible cultivar Black eye increased and reached a peak by the 50th day after sowing, however in the resistant cultivar TVu 1560 the population remained low and plants failed to develop symptoms Younger plants were more susceptible to infection than older ones(Shihata *et al.*,1989).

CB-3(California Black eye-3) was a cultivar resistant to wilt, whereas Grant was reported as a tolerant cultivar (Harris *et al.*, 1991).

The *Vigna unguiculata* cv. California Black eye (CB) 46 (PI548784), released in 1987, was derived as a single-plant selection from a 300-plant BC1 F7 family from the cross CB5 X PI166146. Field and greenhouse testing confirmed that CB46 is resistant to *Fusarium oxysporum* f.sp.

tracheiphilum race 3 (isolate 793) which is common throughout the growing region(Helms *et al.*,1991a).

California Black eye (CB) 88 released in 1989, the *Vigna unguiculata* cv. California Black eye (CB) 88 (PI548785) originated as a mass-selected F4 family from the cross CB5 X 7977, where 7977 is a breeding line from the cross CB5 X PI166146. Resistance to *Fusarium oxysporum* f.sp. *tracheiphilum* race 3, common throughout the California Black eye growing region, was confirmed by field and greenhouse testing (Helms *et al.*,1991b).

Experiments were conducted in glass house to find out efficient management of Fusarium wilt of pigeonpea by Pandey and Upadhyay (1999) and the per cent wilt incidence was calculated as the ratio of number of wilted plants to total number of plants expressed in percentage and found that chemical and biological methods are effective for management of wilt of pigeonpea.

Seventy three *Phaseolus vulgaris* genotypes were screened for resistance to the *Fusarium oxysporum* f.sp. *phaseoli* using artificial inoculum by Buruchara and Camacho (2000). They observed that by increasing inoculum from 10^2 to 10^7 conidia per ml did not affect the resistance of cultivars RWR 950 and G 685 but in the susceptible varieties G 2333 and MLB-48-49A it resulted in early appearance of wilt with high incidence and severity of the disease.

According to Ehlers *et al.* (2000) CB-27 was found to be resistant to both race 4and 5 of Fusarium wilt and it was a cowpea cultivar developed by University of California.

The response of 23 bean cultivars to four physiological races of Fusarium wilt (caused by *Fusarium oxysporum* f.sp. *phaseoli*) was evaluated by Sala *et al.* (2001). The roots of seven day old seedlings grown in sterilized sand were immersed for ten minutes in an inoculum suspension of 10^6 spores per ml. Evaluation was performed 25-30 days after inoculation

using the scale from 0 (without symptoms) to 4 (wilted or died). Plants with ratings 0 to 2 were considered resistant and those with ratings of 3 to 4 were susceptible. Among the cultivars, IAC-Maravilha was susceptible to all the races of *F. oxysporum* f.sp. *phaseoli*, while Apore, FT 120, Carioca-MG, IAC-Carioca, IAC-Una, IAPAR 14, IAPAR 31, IAPAR 44, Perola, Ruda, Jalo Precoce and FT Bonito were resistant to all physiological races of the pathogen.

Cavalcanti *et al.* (2002) studied the efficiency of two inoculation methods in the assessment of resistance of 16 cultivars and lines of common bean to *Fusarium oxysporum* f. sp. *phaseoli*. They revealed that the root immersion method was more effective than the soil perforation method in assessing common bean resistance to Fusarium wilt. In the study, the cultivars Goiano Precoce, RH 3104 and IPA-9 were the most resistant genotypes, whereas LM 93204247, LM 93204296 and IPA-1 were the most susceptible ones.

The reaction of selected genotypes of chickpea against Fusarium wilt race 1 was studied in pot culture by Ravi *et al.* (2003) and reported that resistant genotype WR-315 did not show wilting till maturity and the genotypes have been grouped into three different groups *viz.*, early wilting, late wilting and no wilting.

A set of 226 pigeonpea genotypes were screened to assess Fusarium wilt resistance and 105 genotypes were resistant (0-10 per cent wilt), 33 genotypes were moderately resistant (10-30 per cent wilt) and 88 genotypes were susceptible (>30 per cent wilt) against *Fusarium udum*. Resistant genotypes had higher phenol and sugar content than susceptible genotypes (Madhukeshwara *et al.*, 2004).

In a field screening program for Fusarium wilt resistance, 30 yard long bean genotypes were evaluated on the basis of disease intensity percentage. Genotypes showed significant differences in the degree of disease susceptibility, the genotypes Thiruvananthapuram local-1 and

Thiruvananthapuram local-3 recorded high yield with moderately resistant to Fusarium wilt, while VS 86, Malika and Varuvila local-1 showed high yield with moderately susceptibility. So these genotypes can be used as parents for further crop improvement programme for Fusarium wilt resistance (Madhukumar, 2006).

Materials and Methods

3. MATERIALS AND METHODS

The investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2004-2006. The work is a continuation of the Post Graduate project entitled "Genetic variability for yield and Fusarium wilt resistance in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)". The aim was to study the combining ability variances and the nature of gene action involved in important quantitative and biochemical characters and Fusarium wilt resistance in Line x Tester progenies of yard long bean. The field study was conducted in two experiments *viz.*,

Experiment-I - crossing block.

Experiment-II (a) - field evaluation of F_1s and parents.

II (b) - pot culture studies for screening for Fusarium wilt disease resistance among lines, testers and their progenies.

The details of the experiments conducted and the statistical analysis carried out are as follows.

3.1 MATERIALS

3.1.1 Experiment-I and Experiment-II

The basic material for the study included 5 yard long bean genotypes having high yield and moderate Fusarium wilt resistance and 3 genotypes having high Fusarium wilt resistance selected as lines and testers respectively from the previous project. The lists of the genotypes used as lines and testers are given in the Table 1.

3.2 METHODS

Layout and conduct of the experiments.

Table 1. List of Genotypes used as Lines and Testers

	Genotypes	Notation
Lines	Vellayani local	Vellayani local
	Varuvila-2	Varuvila-2
	VS-86	VS-86
	Palapoor local -1	P-1
	Malika	Malika
Testers	Thiruvananthapuram local-1	TVM-1
	KMV-1	KMV-1
	Thiruvananthapuram local-3	TVM-3

Plate 1. Field view - Evaluation of F_1's and parents

3.2.1 Experiment-I

Based on the previous experiment, five lines and three testers were selected as parents . Experimental design is as follows;

Design – Randomised Block Design

Replications – 3

Treatments – 8 (5 lines + 3 testers)

Normal cultural practices as per the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 2002) were adopted. For crossing, the flower buds due to open on the next day were selected and emasculated on the previous evening. For emasculation, the rest of the flowers and buds in a branch, except for the selected bud is removed. The stamens of selected bud was removed with a pair of fine forceps by gently pushing the keel petals apart. The emasculated floral branch was then bagged. Ripe anthers were collected in the following morning and pollination was done by gently pressing the ripe anthers against the stigma. The flowers were again bagged after pollination. The covers were removed a day after pollination. Pollination was done early in the morning between 6.30 and 8.00 am. The crossed as well as selfed flowers were labelled. The labelled pods were harvested separately on maturity and the seeds of parents and hybrids were collected.

3.2.2 Experiment-II

3.2.2.1 Experiment-II(a)

The layout of the design is as follows;

Design – Randomised Block Design

Replications - 3

Treatments – 23 (15 crosses + 8 parents)

Seeds were sown in rows 1m apart with spacing of 0.3 m between plants.

Plate 2. *Fusarium oxysporum* culture

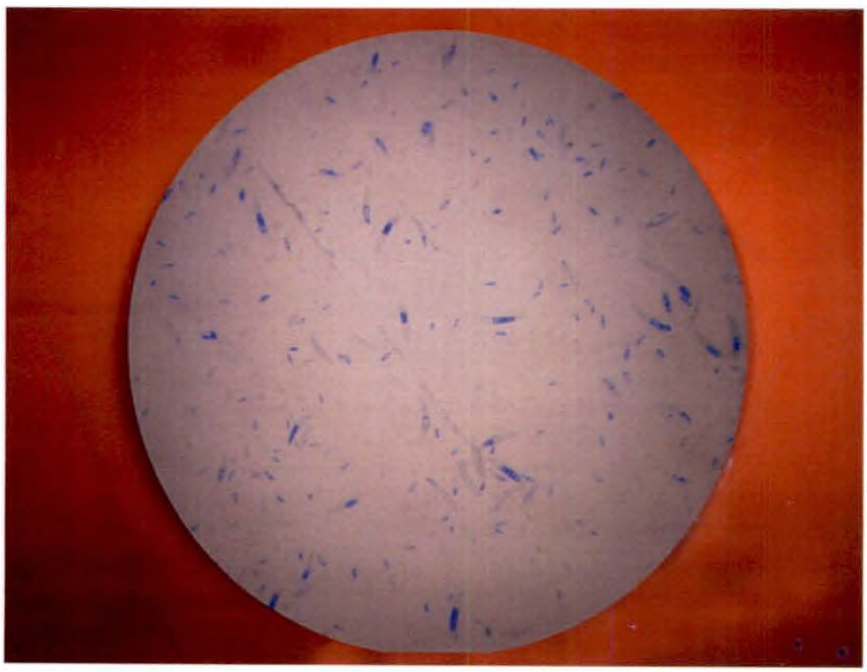


Plate 3. Conidia of *Fusarium oxysporum*

In each replication nine plants per genotype were taken.. Normal cultural practices as per the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 2002) were adopted. Field view for the evaluation of F_1s and parents for various yield and biochemical traits are given in Plate 1.

3.2.2.2 Experiment-II (b)

Pot culture studies were carried out in Completely Randomised Design with two replications during July 2006(Plate 6).

3.2.2.2.1 Isolation of the Pathogen

Cowpea plants showing typical yellowing and wilting symptoms were collected from Fusarium wilted cowpea fields of College of Agriculture, Vellayani, Thiruvananthapuram District of Kerala. Pathogen was isolated following the standard tissue isolation technique. The root along with collar portion of the wilted cowpea plants were washed in tap water and cut into small bits. The bits were then surface sterilized with 0.1 per cent mercuric chloride solution for one minute followed by washing in sterile water 2-3 times. The sterilized pieces were then transferred into sterile petridishes containing Potato Dextrose Agar (PDA) medium under aseptic conditions .The plates were then incubated at room temperature. On the third day onwards whitish fungal mycelial growth was visible from the plant bits. The mycelial bits were transferred to Potato Dextrose Agar (PDA) plates under aseptic condition. When full growth of the mycelium was observed in the petriplates, bits of the mycelium were transformed to Potato Dextrose Agar (PDA) slants under aseptic conditions and kept under room temperature. When full growth of the pathogen was visible the slants were transferred to refrigerator for further studies. Thus the culture of the pathogen was maintained (Plate 2).Periodic subculturing were made for pathological studies.

3.2.2.2.2 Identification of the Pathogen

Slide culture studies were made for studying the morphology of the pathogen. Based on the conidial morphology and the cultural characteristics, the

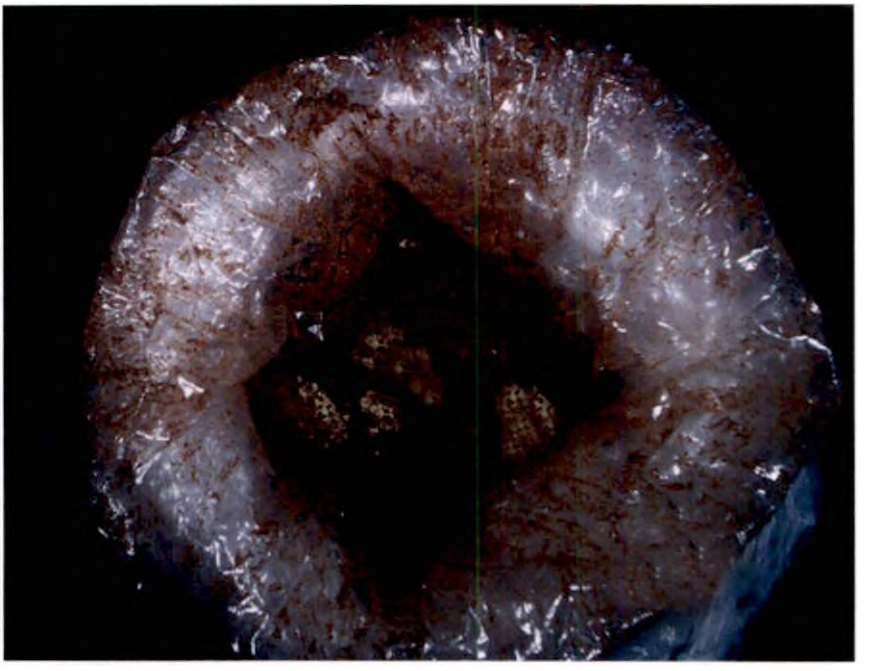


Plate 4. Mass multiplication of *F. oxysporum* in rice bran

Plate 5. Seed treatment with inoculum

pathogen was identified as *Fusarium oxysporum*. Further confirmation was made by comparing the culture with the available culture of Fusarium in the Department of Plant Pathology, College of Agriculture, Vellayani.

3.2.2.2.3 Preparation of Pathogen Inoculum

The tube culture was mass multiplied in PDA in petridishes for inoculation in the rice bran. Fusarium was mass multiplied in rice bran since this is a cheap medium for inoculum multiplication. The materials required for mass multiplication of the pathogen inoculum were

Rice bran -1 kg

Sucrose -20 g

Multi vitamin tablets -3

Water –sufficient to moisture

Inoculum -10 discs (3 mm)

For the present study, 3 kg of inoculum was prepared as above for application in pots. Rice bran was mixed with multi vitamin tablets and sucrose. The mixture was moistened with water sufficient enough to promote fungal growth. This mixture is taken in polythene bags and sterilised in autoclave at 121.5°C for 20 minutes. Seven days old actively growing culture discs of *Fusarium* was aseptically transferred sufficiently into the polythene bags and incubated at room temperature for 15 days to develop fungal growth (Plate 4).

3.2.2.2.4 Application of Pathogen

3.2.2.2.4.1 Seed treatment

One gram of the pathogen inoculum was taken in a plastic container. The bran inoculum mix was moistened with sterile water. Five seeds each of parents and crosses were seeded in the bran inoculum mix and kept for 24 hours. These treated seeds were used for further screening studies (Plate 5).

Plate 6. Pot culture experiment

Plate 7. Application of inoculum in pots at the time of sowing

3.2.2.2.4.2 Soil application

Mass multiplied *Fusarium* inoculum was applied to the pot @ 5g/kg of soil. The inoculum was thoroughly mixed with the soil (Plate 7). Two days after inoculum application, the treated seeds of parents and crosses were sown in pots. A second application was done seven days after sowing at the root zone and the soil was mixed thoroughly so as to make the soil maximum sick.

3.2.2.2.5 Disease Intensity

Observations were taken on number of seeds germinated and ungerminated and percentage death was calculated for lines , testers and crosses.

3.2.3 Biometric Observations

Seeds obtained from experiment I were used to raise the crop for experiment II(a).Five plants per genotype per replication were selected for recording the biometric observation in Experiment II(a). The mean value of five observational plants were recorded. In experiment II(b), five seeds each of 8 parents and 15 crosses were sown in each pot and observations on seedling damping off were taken on tenth and twentieth days after sowing. Angular transformation was made and percentage death was calculated.

3.2.3.1 Yield Traits

3.2.3.1.1 Days to 50% flowering

Number of days taken from sowing to flowering of 50 percent of the plants were recorded.

3.2.3.1.2 Days to first harvest

Number of days taken from sowing to first harvest was recorded.

3.2.3.1.3 Length of harvest period (days)

Number of days taken from first harvest to the last harvest were recorded.

3.2.3.1.4 Crop duration (days)

Number of days taken from sowing to the last harvest were recorded.

3.2.3.1.5 Primary branches per plant

Number of primary branches were recorded on each observational plant at the time of final harvest.

3.2.3.1.6 Main stem length (cm)

Length of the vine from the base of the plant to the terminal bud was measured and recorded.

3.2.3.1.7 Pod clusters per plant

Number of pod clusters of the observational plants were recorded

3.2.3.1.8 Pods per plant

Pods obtained in each harvest from each of the observational plants were counted and recorded.

3.2.3.1.9 Pod yield per plant

Weight of pods from observational plants were recorded after each harvest. Total weight of pods of each observational plant was calculated and recorded.

3.2.3.1.10 Pods per cluster

Number of pods of each cluster of observational plants was recorded and mean worked out.

3.2.3.1.11 Pod weight (g)

Weight of five randomly selected individual pods were recorded from each observational plant and mean worked out.

3.2.3.1.12 Pod length (cm)

Length of five randomly selected individual pods were recorded from each observational plant and mean worked out.

3.2.3.1.13 Pod breadth (cm)

Breadth of five randomly selected individual pods were recorded from each observational plant and mean worked out.

3.2.3.1.14 Seeds per pod

Number of seeds of five randomly selected individual pods were recorded from each observational plant and mean worked out.

3.2.3.1.15 Seed colour

Colour of the seeds from pods of observational plants were recorded.

3.2.3.1.16 100-seed weight (g)

The weight of 100 randomly selected seeds from each observational plant was recorded.

3.2.3.1.17 Root weight per plant (g)

The average fresh weight of uprooted roots of five observational plants at the time of harvesting were recorded.

3.2.3.1.18 Nodules per plant

The number of separated nodules from plants uprooted at harvest were recorded.

3.2.3.2 Biochemical Traits

3.2.3.2.1 Crude fibre content (%)

2g of dried and ground pod was boiled with 200 ml of sulfuric acid for 30 minutes with bumping chips. It was filtered through muslin and washed with boiling water until washings were no longer acidic. Then it is boiled with 200 ml sodium hydroxide solution for 30 minutes and filtered through muslin cloth, washed with 25ml boiling 1.25 per cent sulphuric acid, three 50 ml portions of water and 25 ml alcohol. The residue was removed and transferred to ashing dish. The residue was dried for 2 hours at 130 ± 2°C, cooled in a dessicator and

weighed. It was ignited for 30 min at 600± 15°C , cooled in a dessicator and weighed.

3.2.3.2.2 Protein content (g)

Total soluble protein content was estimated as per the procedure described by Bradford (1976). One g of sample was taken and ground in a pestle and mortar with 10 ml of 0.1 M Acetate buffer pH 4.7.The extract was then centrifuged at 5000 rpm at 4°c for 15 minutes. The supernatant was transferred into a test tube and residue was discarded. The reaction mixture contained 0.5 ml of sample extract + 0.5 ml distilled water + 5 ml of dye solution (Coomassie brilliant blue G250). The absorbance was read at 595 nm in a spectrophotometer (Systronics UV-VIS Spectrophotometer 118) against reagent blank. Using BSA standard graph deduced the protein content as albumin equivalent of soluble protein per gram on fresh weight basis.

3.2.3.2.3 Peroxidase

The procedure described by Srivastava (1987) was used for determining peroxidase activity. Leaf samples (200 mg) were weighed and homogenized in 1ml of 0.1 M sodium phosphate buffer to which a pinch of PVP was added. The homogenization was done at 4°C. The homogenate was strained using cotton and centrifuged at 5000 rpm for 10 minutes at 4°C. The supernatant was used as the enzyme extract for the assay of peroxidase activity.

The reaction mixture consisting of 1ml of 0.05 M Pyrogallol and 1ml of 1% Hydrogen peroxide was taken in both reference and sample cuvettes, mixed and kept in a spectrophotometer and the reading was adjusted to zero at 420 nm . The enzyme reaction was started by adding 50 ml of enzyme extract into sample cuvettes and change in absorbance was measured at 30 seconds interval up to 180 seconds.

3.2.3.2.4 Poly phenol oxidase

Poly phenol oxidase activity was determined as per the procedure given by Mayer et al. (1965). The enzyme extract is prepared as per the procedure given for

the estimation of peroxidase. The reaction mixture contained 1 ml Sodium phosphate buffer pH 6.5 and 1 ml of 0.01 M catechol. The cuvettes were placed in a spectrophotometer (Systronics UV-VIS Spectrophotometer 118) and absorbance was set to zero. The reaction was started after adding 50ml of enzyme extract. The change in absorbance was recorded at 495 nm and PPO activity was expressed as changes in the absorbance of the reaction mixture per minute per g on fresh weight basis.

3.2.3.2.5 Total phenols

Total phenols estimated as per the procedure given by Malick and Singh (1980). Weigh exactly 1g of the sample and grind it with a pestle and mortar in 10 times volume of 80% ethanol. centrifugate the homogenate at 10,000 rpm for 20 minutes. Save the supernatant. Re-extract the residue with five times the volume of 80% ethanol, centrifuge and save the supernatants. Evaporate the supernatant to dryness. Dissolve the residue in a 5ml volume of distilled water, pipette out different aliquots (0.2 to2 ml) into test tubes and make up the volume in each tube to 3 ml with water. Add 0.5 ml of Folin-Ciocalteau reagent. After three minutes add 2 ml of 20 per cent Na2CO3 solution to each tube. Mix thoroughly and place the tubes in a boiling water for exactly one minute, cool and measure the absorbance at 650 nm against a reagent blank. A standard curve was prepared using different concentrations of catechol and from the standard curve, the concentrations of phenols in the test sample was found out and expressed as mg phenols/100g material.

3.3 STATISTICAL ANALYSIS

3.3.1 Combining Ability Analysis

Combining ability analysis of the Line x Tester was done through ANOVA technique (Dabholkar, 1992) as follows (Table 2).

Table 2. Analysis of variance for line x tester design

Source	df	SS	MS	Expected mean square
Replication	r – 1	SSR	MSR	
Genotypes	n – 1	SSG	MSG	
Parents	(l + t) – 1	SSP	MSP	
Parents vs. crosses	1	SSO	SMO	
Crosses	l x t – 1	SSC	MSC	
a. Lines	l – 1	SSL	M_L	$\sigma^2 + r\sigma^2 sca + rt\sigma^2 gca$
b. Testers	t – 1	SST	M_T	$\sigma^2 e + r\sigma^2 sca + rl\ \sigma^2 gca$
c. Line x tester	(l – 1) (t – 1)	SSLT	M_{LT}	$\sigma^2 + r\sigma^2_{sca}$
Error	(n – 1) (r – 1)	SSE	M_e	σ^2_e
Total	nr – 1			

Where, n = number of treatment materials l + t + l x t

r = number of replications

l = number of lines

t = number of testers

3.3.1.1 Estimation of General and Specific Combining Ability Effects

General combining ability effect (*gca*) of parents and specific combining ability effect (*sca*) of hybrids were estimated using the following model.

$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$

Where, μ = population mean

g_i = *gca* effect of i^{th} line

g_j = *gca* effect of j^{th} tester

s_{ij} = *sca* effect of ij^{th} hybrid

e_{ijk} = error associated with ijk^{th} hybrid.

$i = 1, 2, \ldots, l$

$j = 1, 2, \ldots, t$

$k = 1, 2 \ldots, r$

The individual effects were estimated as follows:

(i) Mean $= \dfrac{X\ldots}{rlt}$

(ii) *gca* effect of lines $= \dfrac{X_{i..}}{rt} - \dfrac{X\ldots}{rlt}$

(iii) *gca* effect of testers $= \dfrac{X.j.}{rl} - \dfrac{X\ldots}{rlt}$

(iv) *sca* effect of hybrids

$$S_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{rt} - \frac{X_{.j.}}{rl} + \frac{X\ldots}{rlt}$$

where,

$X\ldots$ = totality of observations on all hybrids over 'r' number of replications.

$X_{i..}$ = totality of observations on i^{th} line over 't' tester and 'r' replications

$X_{.j.}$ = totality of observations on j^{th} tester over 'l' lines and 'r' replications

$$t = \frac{(\text{Effect})}{\text{SE (effect)}}$$

Where,

$$\text{SE of } gca \text{ (lines)} = \sqrt{\frac{M_e}{rt}}$$

$$\text{SE of } gca \text{ (testers)} = \sqrt{\frac{M_e}{rl}}$$

$$\text{SE of } sca \text{ (hybrids)} = \sqrt{\frac{M_e}{r}}$$

3.3.1.2 Combining Ability Analysis

The GCA variance for lines and testers and SCA variance for the hybrids were calculated as follows:

$$\sigma^2 \text{ GCA (lines)} = \frac{M_L - M_{LT}}{rt} = \text{Cov. H.S. (lines)}$$

$$\sigma^2 \text{ GCA (testers)} = \frac{M_T - M_{LT}}{r \times l} = \text{Cov. H.S. (testers)}$$

$$\sigma^2 \text{ SCA (hybrids)} = \frac{M_{LT} - M_e}{r}$$

3.3.1.3 Gene Action

After estimating the variances due to general combining ability (σ^2 SCA) the gene action was worked out as :

When inbreeding is absent (F = 0)

σ^2 GCA = ¼ σ^2 A

σ^2 SCA = ¼ σ^2 D

So, σ^2A = 4 σ^2 GCA

σ^2D = 4 σ^2 SCA

3.3.1.4 Proportional Contribution of Lines, Testers and Line x Testers to the Total Sum of Squares of the Hybrids

$$\text{Contribution of lines} = \frac{\text{S.S. (lines)}}{\text{S.S. (hybrids)}} \times 100$$

$$\text{Contribution of testers} = \frac{\text{S.S. (testers)}}{\text{S.S. (hybrids)}} \times 100$$

$$\text{Contribution of lines x testers} = \frac{\text{S.S. (line x tester)}}{\text{S.S. (hybrids)}} \times 100$$

3.3.2 Estimation of Heterosis

Heterosis (expressed in percentage) was estimated for all the characters over mid parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis) as suggested by Rai (1979).

3.3.2.1 Relative Heterosis

Relative heterosis was estimated as the percentage deviation of the mean performance of F_1 ($\overline{F_1}$) over the mean performance of the parents ($\overline{MP}$).

$$\text{Relative heterosis (RH)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where MP = mid parental mean value

$\overline{F_1}$ = average performance of F_1

3.3.2.2 Heterobeltiosis

Heterobeltiosis was estimated in comparison to the better parent as

$$\text{Relative heterosis (HB)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where $\overline{BP}$ = better parental mean of a particular cross.

3.3.2.3 Standard Heterosis

Standard heterosis was estimated in comparison to the standard variety (Malika) as

$$\text{Relative heterosis (HB)} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

Where $\overline{SP}$ = mean of the standard variety.

The significance of different types of heterosis was tested by 't' test with (n – 1) (r – 1) degrees of freedom. The critical difference (CD) for comparison of differences of F_1 is

$$F_1 \text{ with } \overline{MP} \text{ is } = \cdot\ t_\alpha \sqrt{\frac{3\ M_e}{2r}}$$

F_1 with $\overline{BP}$ is = $t_\alpha \sqrt{\frac{2 M_e}{r}}$

F_1 with $\overline{SP}$ is = $t_\alpha \sqrt{\frac{2 M_e}{r}}$

where t_α is students t table value at five per cent level for $(n-1)(r-1)$df.

Results

4. RESULTS

Fifteen hybrids derived from crosses between five lines and three testers were evaluated along with their parents for heterosis and combining ability for 22 characters namely, days to 50% flowering, length of harvest, crop duration, primary branches per plant, main stem length, pod clusters per plant, pods per plant, pod yield per plant, pods per clusters, pod weight, pod length, pod breadth, seeds per pod, 100 seed weight, root weight per plant, nodules per plant, days to first harvest, crude fibre content, protein content, peroxidase, polyphenol oxidase and total phenols. Apart from these Fusarium wilt disease intensity were also studied.

The data were subjected to line x tester analysis. Abstract of ANOVA of characters are represented in Table 3 and the results are presented below. All the characters showed significant differences among the treatments. Variation in seed colour among lines, testers and hybrids were represented in Table 4,Plate 9.

4.1 MEAN PERFORMANCE

Significant genotypic differences were observed for all the characters. The mean performance of lines, testers and their hybrids for different characters are presented in Table 5a and 5b.

4.1.1 Days to 50% flowering

Minimum days to 50% flowering was shown by VS-86 and Varuvila-2(46.80) which was on par with Vellayani local(47.40) among lines. Among testers, TVM-1(45.30) showed minimum value which was on par with TVM-3 (46.20).Among crosses, minimum value was shown by VS-86 x TVM-1(45.47) which was on par with Vellayani local x TVM-1(46.53),Varuvila-2 x TVM-1 (45.53) and VS-86 x TVM-3(46.00).

Table 3 Abstract of ANOVA of the characters (MSE)

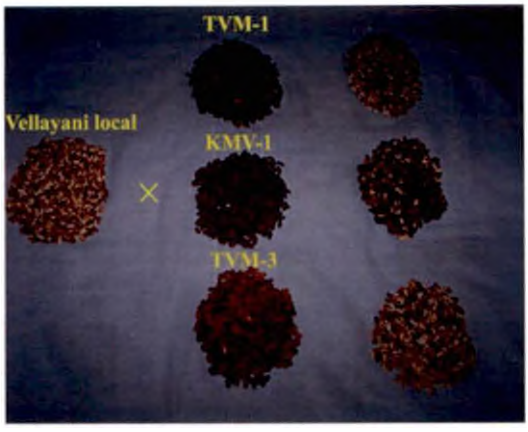
Source	df	Days to 50 per cent flowering	Length of harvest period (days)	Crop duration (days)	Primary branches per plant	Main stem length (cm)	Pod clusters per plant	Pods per plant	Pod yield per plant	Pods per clusters	Pod weight (g)	Pod length (cm)
Genotypes	22	9.37	15.35	6.17	0.059	1875.17	7.70	21.37	10356.27	0.66	38.68	118.92
Lines	4	7.45	14.01	4.25	0.071	2925.63	10.23	64.18	3055.04	1.06	16.47	101.17
Testers	2	34.49	11.87	2.37	0.074	1439.09	0.73	13.02	28186.31	0.67	21.19	69.66
L x T	8	4.51	12.42	5.98	0.072	377.82	0.84	15.03	1476.49	0.67	35.78	71.20
Parents	7	10.02	22.15	9.25	0.038	3378.33	9.76	8.98	19462.92	0.20	59.51	211.97
Crosses	14	9.63	12.79	4.97	0.072	1257.38	3.50	28.78	5743.19	0.69	28.17	79.54
Parent vs Crosses	1	1.14	3.61	1.44	0.017	2.21	52.09	4.42	11192.67	3.38	40.01	18.90
Error	44	0.67	0.55	0.50	0.25	5.17	0.02	0.02	8.08	0.01	0.34	1.06

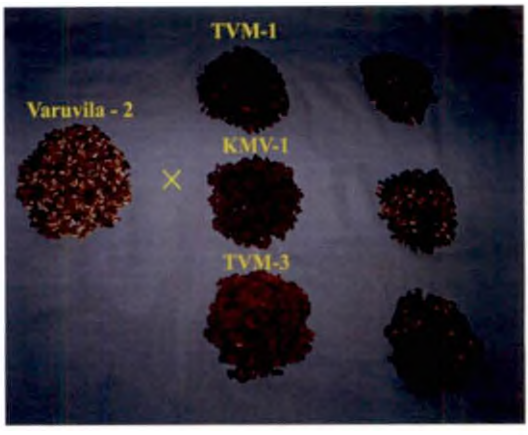
Table 3 Continued

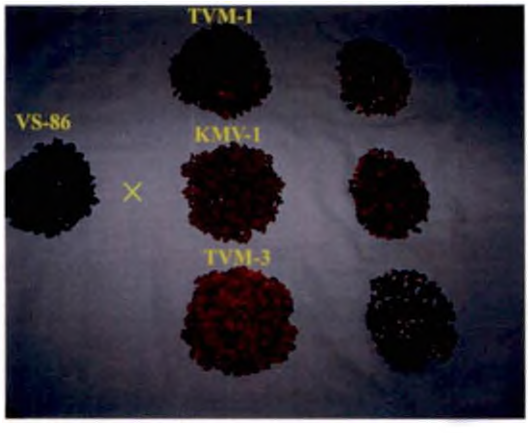
Source	df	Pod breadth (cm)	Seeds per pod	100 seed weight (g)	Root weight per plant (g)	Nodules per plant	Days to first harvest	Crude fibre content (%)	Protein content (g)	Peroxidase	Polyphenol oxidase	Total phenols
Genotypes	22	0.06	19.65	13.91	85.29	25.52	2.69	0.09	260.50	0.006	0.00071	0.17
Lines	4	0.04	10.43	24.52	101.79	22.63	4.65	0.08	482.19	0.004	0.00004	0.08
Testers	2	0.002	39.05	8.36	48.59	23.79	7.06	0.03	35.76	0.0004	0.00003	0.58
L x T	8	0.08	15.31	15.45	83.93	30.22	0.99	0.05	89.25	0.003	0.00022	0.15
Parents	7	0.04	27.12	8.97	100.06	25.62	2.63	0.16	430.26	0.012	0.00110	0.14
Crosses	14	0.06	17.31	17.03	83.98	27.13	2.90	0.05	193.87	0.003	0.00050	0.19
Parent vs Crosses	1	0.16	0.20	5.01	0.12	2.25	0.23	0.06	4.93	0.019	0.00040	0.23
Error	44	0.001	0.37	0.103	0.42	0.21	0.03	0.014	12.92	0.0004	0.00001	0.03

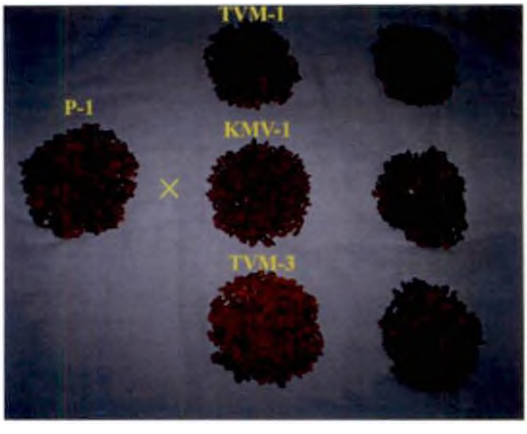
Table 4.Seed colour variation among lines, testers and hybrids

Name	Colour
Vellayani local	Variegated with brown and white colour
Varuvila-2	Variegated with brown and white colour
VS-86	Black
P-1	Brown
Malika	Brown with white coloured tip
TVM-1	Dark brown
KMV-1	Dark brown
TVM-3	Light brown
Vellayani local x TVM-1	Variegated with brown and white colour
Vellayani local x KMV-1	Brown and variegated with white
Vellayani local x TVM-3	Variegated with brown and white colour
Varuvila-2 x TVM-1	Variegated with brown and white
Varuvila-2 x KMV-1	Brown as well as variegation with white
Varuvila-2 x TVM-3	Black, brown and variegation seen
VS-86 x TVM-1	Black and brown colour
VS-86 x KMV-1	Brown
VS-86 x TVM-3	Variegated with black and white
P-1 x TVM-1	Brown
P-1 x KMV-1	Black and dark brown
P-1 x TVM-3	Brown
Malika x TVM-1	Brown
Malika x KMV-1	Dark brown
Malika x TVM-3	Brown









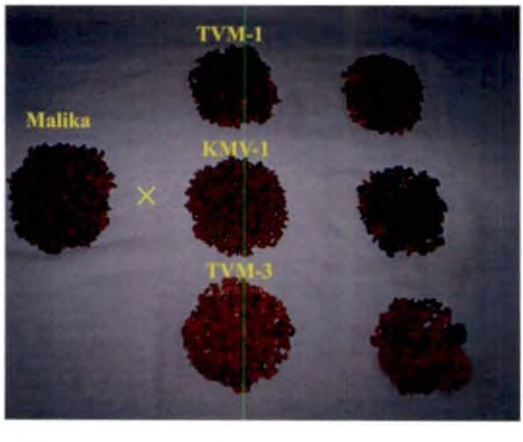


Plate 9. Crosses showing variation in seed colour

4.1.2 Length of harvest period(days)

Maximum length of harvest periods was noted for line VS-86(31.73) which was on par with Malika(31.29).The line Vellayani local (25.4) showed minimum value which was on par with Varuvila-2 (26.00).Testers,TVM-3 (29.40) and KMV-1(24.40) showed the maximum and minimum value respectively. The crosses VS-86 x KMV-1(24.27) showed minimum value which was on par with Varuvila-2 x KMV-1(24.87) and VS-86 x TVM-1 (24.73).Maximum value was noted for Malika x TVM-1(31.27).

4.1.3 Crop duration(days)

The line Vellayani local(81.47) showed minimum crop duration where as maximum value was noted for Malika(87.00) which was on par with VS-86(86.27).Among testers,TVM-3(84.80) showed maximum value which was on par with TVM-1(84.40) .KMV-1(82.80) recorded minimum value. Among crosses, minimum value was noted for VS-86 x KMV-1(82.93) which was on par with Varuvila-2 x TVM-1(83.67),Varuvila-2 x KMV-1(83.13), VS-86 x TVM-3(83.53),P-1 x TVM-3(83.40) and Malika x TVM-3(83.73)

4.1.4 Primary branches per plant

No significance was observed for lines and testers. The mean primary branches per plant ranged from 3.53 (VS-86 and Varuvila-2) to 3.73 (P-1) in lines, 3.47 (KMV-1) to 3.80(TVM-1) in testers. Among crosses, maximum value was noted for Malika x TVM-3(3.87) .Minimum value was shown by P-1 x KMV-1(3.33).

4.1.5 Main stem length(cm)

The maximum main stem length was noticed for the line, P-1(539.73) and minimum for VS-86(448.20)which was on par with Varuvila-2 (450.53).Among testers value ranged from 476.20 (TVM-1) to 524.07 (TVM-3) .The cross VS-86 x KMV-1(453.20) and P-1 x TVM-1(519.53)showed minimum and maximum value respectively.

Table 5a. Mean performance of Lines and Testers for various characters

Characters / Treatments	Days to 50 per cent flowering	Length of harvest period (days)	Crop duration (days)	Primary branches per plant	Main stem length (cm)	Pod clusters per plant	Pods per plant	Pod yield per plant	Pods per clusters	Pod weight (g)	Pod length (cm)
Line											
Vellayani local	47.40	25.40	81.47	3.67	507.27	5.87	9.27	266.20	2.40	17.40	37.27
Varuvila-2	46.80	26.00	84.27	3.53	450.53	9.67	12.73	247.47	2.27	17.33	28.67
VS-86	46.80	31.73	86.27	3.53	448.20	7.73	8.47	415.80	2.20	25.27	48.00
P-1	50.47	28.40	84.33	3.73	539.73	4.67	10.73	272.73	2.73	14.20	45.49
Malika	48.93	31.27	87.00	3.67	495.93	5.80	10.00	276.80	2.73	14.13	35.33
Testers											
TVM-1	45.53	26.87	84.40	3.80	476.20	6.47	13.67	309.27	2.33	25.33	25.73
KMV-1	50.07	24.40	82.80	3.47	469.27	4.13	10.73	173.60	2.20	16.87	32.13
TVM-3	46.20	29.40	84.80	3.67	524.07	5.00	11.60	156.13	2.00	16.40	45.93
SE ±	0.47	0.43	0.41	0.09	1.31	0.08	0.08	1.64	0.06	0.34	0.59
CD	1.34	1.23	1.17	0.26	3.74	0.23	2.02	4.68	0.17	0.97	1.68

Table 5a. Continued

Characters / Treatments	Pod breadth (cm)	Seeds per pod	100 seed weight (g)	Root weight per plant (g)	Nodules per plant	Days to first harvest	Crude fibre content (%)	Protein content (g)	Peroxidase	Polyphenol oxidase	Total phenols
Line											
Vellayani local	1.13	14.67	18.40	20.80	15.20	55.47	1.84	50.00	0.07	0.0012	11.10
Varuvila- 2	0.87	12.67	19.20	21.27	13.73	55.00	2.03	79.00	0.25	0.0030	11.17
VS-86	0.93	20.80	16.87	32.80	20.60	57.53	1.64	45.67	0.11	0.0020	11.20
P-1	0.74	13.73	19.27	21.73	16.13	57.13	2.37	78.33	0.11	0.0050	11.03
Malika	0.98	14.00	15.73	27.27	19.40	56.00	2.00	66.00	0.12	0.0040	10.95
Testers											
TVM-1	0.99	11.67	19.73	17.00	13.47	56.27	1.72	69.67	0.11	0.0040	11.38
KMV-1	0.91	15.60	16.80	23.93	18.07	57.63	1.78	65.33	0.04	0.0060	10.83
TVM-3	0.79	11.27	15.20	32.80	20.60	56.27	2.03	68.00	0.07	0.0030	10.68
SE ±	0.02	0.11	0.19	0.37	0.26	0.09	0.07	2.07	0.01	0.0002	0.09
CD	0.06	0.31	0.54	1.06	0.74	0.26	0.20	5.91	0.03	0.0005	0.26

4.1.6 Pod clusters per plant

The pod clusters per plant ranged from 4.67 (P-1) to 9.67 (Varuvila-2) in lines, 4.13 (KMV-1) to 6.47 (TVM-1) in testers. Maximum value was noted for the cross Vellayani local x TVM-1(5.73) which was on par with Vellayani local x TVM-3(5.67) and minimum for P-1 x TVM-3(2.20).

4.1.7 Pods per plant

The line Varuvila-2(12.73) exhibited maximum value which was on par withP-1(10.73) and minimum value was shown by VS-86(8.47) which was on par with Vellayani local(9.27) and Malika(10.00). The tester TVM-1 showed maximum value whereas KMV-1(10.73) exhibited minimum value which was on par with TVM-3(11.60).Among crosses, Vellayani local x TVM-1(16.87) exhibited maximum value whereas minimum value was shown byP-1x KMV-1 (4.93) which was on par with P-1 x TVM-3(6.33).

4.1.8 Pod yield per plant

The pod yield per plant ranged from 247.47 (Varuvila-2) to 415.80 (VS-86) in lines which was significantly higher than others. It ranged from 173.6 (KMV-1) to 309.27 (TVM-1) in testers. Among crosses it ranged from 192.47 (Vellayani local x TVM-3) to 323.93 (VS-86 x TVM-1).This cross was highly significant and superior than others.

4.1.9 Pods per clusters

The maximum value among lines were shown by P-1 and Malika(2.73) and minimum by VS-86(2.20) which was on par withVaruvila-2(2.27).Among testers,TVM-1(2.33) showed maximum value which was on par with KMV-1 (2.20).The cross, Varuvila-2 x TVM-1(2.86) exhibited maximum value which was on par with VS-86 x TVM-3(2.73).Minimum value was noticed for P-1 x KMV-1 (1.27) which was on par with Malika x TVM-1(1.40).

4.1.10 Pod weight (g)

The maximum pod weight was noticed for lineVS-86(25.27) and minimum for Malika(14.23) which was on par with P-1(14.20). Among testers, TVM-1(25.33) showed maximum value whereas minimum value was shown by TVM-3(16.40) which was on par with KMV-1(16.87). Among crosses, Malika x TVM-1(23.07) showed maximum value and Malika x TVM-3(12.87) which was on par with VS-86 x TVM-3(13.07) showed minimum value.

4.1.11 Pod length(cm)

The pod length ranged from 28.67 (Varuvila-2) to 48.00 (VS-86) in lines, 25.73 (TVM-1) to 45.93 (TVM-3) in testers and 25.33 (VS-86 x TVM-3) to 47.87 (P-1 x KMV-1) in hybrids. The mean values of the lines, testers and crosses with maximum values of this character was significantly higher than other treatments.

4.1.12 Pod breadth(cm)

The pod breadth ranged from 0.74 (P-1) to 1.13 (Vellayani local) in lines, 0.79 (TVM-3) to 0.99 (TVM-1) in testers. Among crosses, maximum value was shown by Malika x TVM-1(1.09) which was on par with VS-86 x TVM-3(1.07).Minimum value was shown by P-1 x KMV-1(0.66) which was on par with VS-86 x TVM-1(0.68),Varuvila-2 x TVM-3 and Malika x TVM-3 (0.69),Vellayani local x KMV-1 and P-1 x TVM-3(0.72).

4.1.13 Seeds per pod

The seeds per pod ranged from 12.67 (Varuvila-2) to 20.8 (VS-86) in lines, 11.27 (TVM-3) to 15.60 (KMV-1) in testers and 10.87 (Varuvila-2 x TVM-1) to 18.27 (Vellayani local x KMV-1) in hybrids.

4.1.14 100 seed weight (g)

The maximum value for 100 seed weight was shown byP-1(19.27) which was on par with Varuvila-2(19.20) among lines. The line Malika (15.73) showed minimum value. The value ranged from 15.20(TVM-3) to19.73 (TVM-1)

Table 5b. Mean performance of hybrids for various characters

Characters / Treatments	Days to 50 per cent flowering	Length of harvest period (days)	Crop duration (days)	Primary branches per plant	Main stem length (cm)	Pod clusters per plant	Pods per plant	Pod yield per plant	Pods per clusters	Pod weight (g)	Pod length (cm)
Vellayani x T_1	46.53	26.93	85:33	3.73	514.13	5.73	16.87	254.87	2.40	15.20	33.00
Vellayani x T_2	49.20	29.93	85.33	3.47	495.80	4.53	10.60	201.53	2.27	16.33	37.93
Vellayani x T_3	47.07	29.47	84.67	3.67	504.60	5.67	12.33	192.47	1.67	21.20	35.87
Varuvila x T_1	45.53	29.60	83.67	3.73	468.20	5.40	9.47	277.27	1.73	16.20	37.93
Varuvila x T_2	47.93	24.87	83.13	3.73	465.26	4.87	14.00	199.67	2.86	14.07	37.53
Varuvila x T_3	49.27	26.20	86.47	3.73	484.26	5.06	12.00	203.80	2.07	16.47	35.07
VS-86 x T_1	45.47	24.73	84.47	3.86	457.07	4.27	11.73	323.93	2.00	18.13	38.40
VS-86 x T_2	50.13	24.27	82.93	3.86	453.20	5.33	11.93	222.60	1.53	14.47	30.93
VS-86 x T_3	46.00	27.80	83.53	3.60	491.87	4.80	11.40	212.67	2.73	13.07	25.33
P-1 x T_1	48.93	27.47	85.53	3.73	519.53	3.53	10.40	301.07	1.60	16.67	34.40
P-1 x T_2	51.73	26.87	86.53	3.33	495.20	2.67	4.93	201.07	1.27	16.60	47.87
P-1 x T_3	47.80	28.93	83.40	3.60	501.00	2.20	6.33	279.80	1.67	21.80	40.60
Malika x T_1	47.53	31.27	86.73	3.53	506.53	4.00	8.73	281.20	1.40	23.07	41.13
Malika x T_2	49.67	26.20	85.33	3.53	481.27	3.40	7.26	213.80	1.53	16.13	35.20
Malika x T_3	47.87	27.27	83.73	3.87	500.87	3.67	7.53	204.40	1.67	12.87	32.07
SE ±	0.47	0.43	0.41	0.09	1.31	0.08	0.08	1.64	0.06	0.34	0.59
CD	1.34	1.23	1.17	0.26	3.74	0.23	2.02	4.68	0.17	0.97	1.68

T_1 – TVM-1, T_2 – KMV-1, T_3 – TVM-3

Table 5b. Continued

Characters / Treatments	Pod breadth (cm)	Seeds per pod	100 seed weight (g)	Root weight per plant (g)	Nodules per plant	Days to first harvest	Crude fibre content (%)	Protein content (g)	Peroxidase	Polyphenol oxidase	Total phenols
Vellayani local x T_1	0.73	11.87	20.40	23.00	12.93	56.00	1.78	52.67	0.070	0.0022	11.13
Vellayani local x T_2	0.72	18.27	17.00	20.13	20.80	57.07	1.92	58.33	0.050	0.0040	10.57
Vellayani local x T_3	0.93	17.93	19.07	21.60	21.53	56.33	1.89	66.67	0.074	0.0020	10.80
Varuvila-2 x T_1	0.86	10.87	15.27	29.07	14.60	55.00	2.03	70.00	0.135	0.0025	11.10
Varuvila-2 x T_2	0.93	16.13	15.20	32.20	17.60	56.00	1.61	70.33	0.090	0.0030	11.03
Varuvila-2 x T_3	0.69	15.47	15.18	26.87	16.40	55.53	2.07	71.33	0.080	0.0020	10.60
VS-86 x T_1	0.68	15.00	18.60	33.00	15.87	56.60	1.74	50.00	0.060	0.0011	11.07
VS-86 x T_2	0.89	13.27	19.86	17.47	19.67	57.40	1.73	61.67	0.110	0.0034	11.10
VS-86 x T_3	1.07	11.60	16.80	23.00	21.53	56.20	1.72	52.33	0.103	0.0015	10.65
P-1 x T_1	0.78	11.07	20.67	19.13	15.53	57.73	2.04	75.00	0.014	0.0049	11.13
P-1 x T_2	0.66	17.13	16.00	27.13	13.47	58.93	2.02	74.00	0.055	0.0045	11.03
P-1 x T_3	0.72	13.47	15.67	17.80	17.40	55.87	1.93	63.33	0.082	0.0030	10.37
Malika x T_1	1.09	13.53	13.00	22.53	21.47	56.33	1.87	69.33	0.103	0.0040	11.07
Malika x T_2	0.83	13.53	19.13	32.70	19.20	57.00	1.76	67.67	0.046	0.0040	11.03
Malika x T_3	0.69	13.67	14.47	23.53	14.93	55.80	1.84	67.67	0.064	0.0030	11.13
SE ±	0.02	0.11	0.19	0.37	0.26	0.09	0.07	2.07	0.010	0.0002	0.09
CD	0.06	0.31	0.54	1.06	0.74	0.26	0.20	5.91	0.030	0.0005	0.26

in testers. Among crosses, P-1 x TVM-1(20.67) showed maximum value which was on par with Vellayani local x TVM-1(20.40).The cross, Malika x TVM-1 (13.00) showed minimum value.

4.1.15 Root weight per plant(g)

The root weight per plant was maximum for the line VS-86 (32.80).Minimum value was shown by Vellayani local(20.80) which was on par with Varuvila-2(21.27) and P-1(21.73).The value ranged from 17.00(TVM-1) to 32.80(TVM-3) in testers. The cross, VS-86 x TVM-1(33.00) exhibited maximum value which was on par with Varuvila-2 x KMV-1(32.20) and Malika x KMV-1(32.70).Minimum value was shown by VS-86 x KMV-1 (17.47) which was on par with P-1 x TVM-3(17.80).

4.1.16 Nodules per plant

The nodules per plant ranged from 13.73 (Varuvila-2) to 20.60 (VS-86) in lines, 13.47 (TVM-1) to 20.67 (TVM-3) in testers. Among crosses maximum value was shown by VS-86 x TVM-3 and Vellayani local x TVM-3(21.53) which were on par with Malika x TVM-1(21.47) and Vellayani local x KMV-1 (20.80).Minimum value was shown by Vellayani local x TVM-1(12.93) which was on par with P-1 x KMV-1(13.47).

4.1.17 Days to first harvest

The days to first harvest ranged from 55.00 (Varuvila-2) to 57.53 (VS-86) in lines, 56.27 (TVM-1 and TVM-3) to 57.53 (KMV-1) in testers. Among crosses maximum value was shown by P-1 x KMV-1(58.93) and minimum value was shown by Varuvila-2 x TVM-1(55.00) which was on par with Varuvila-2 x TVM-3(55.53).

4.1.18 Crude fibre content(%)

The maximum value was shown by the line P-1(2.37) which was on par with Varuvila-2(2.03) and Malika(2.00). Minimum value was noticed for VS-86 (1.64) which was on par with Vellayani local (1.84). Among testers, minimum value was shown by TVM-1(1.72) which was on par with KMV-1(1.78).Among

crosses, minimum value was exhibited by Varuvila-2 x KMV-1(1.61) which was on par with VS-86 x TVM-3(1.72), VS-86 x KMV-1(1.73), VS-86 x TVM-1 (1.74), Malika x KMV-1(1.76) and Vellayani local x TVM-1(1.78).

4.1.19 Protein content(g)

The protein was maximum for Varuvila-2 (79.00) which was on par with P-1(78.33).Minimum value was shown by VS-86 (45.67) which was on par with Vellayani local (50.00). Among testers, maximum value was shown by TVM-1(69.67) which was on par with TVM-3 (68.00) and KMV-1 (65.33).Maximum value for crosses was shown by P-1 x TVM-1(75.00) which was on par with P-1 x KMV-1(74.00), Varuvila-2 x TVM-3 (71.33),Varuvila-2 x KMV-1(70.33), Varuvila-2 x TVM-1(70.00) and Malika x TVM-1(69.33).

4.1.20 Peroxidase

The peroxidase activity ranged from 0.07 (Vellayani local) to 0.25 (Varuvila-2) in lines, 0.04 (KMV-1) to 0.11 (TVM-1) in testers. Among crosses, maximum value was shown by Varuvila-2 x TVM-1(0.13) which was on par with VS-86 x KMV-1(0.11).Minimum value was shown by P-1x TVM-1 (0.01).

4.1.21 Polyphenol oxidase

The polyphenol oxidase activity ranged from 0.0012 (Vellayani local) to 0.0051 (P-1) in lines, 0.0032 (TVM-3) to 0.0061 (KMV-1) in testers. Among crosses, maximum value was shown by P-1x TVM-1(0.0049) which was on par with P-1 x KMV-1(0.0045).Minimum value was shown by VS-86 x TVM-1(0.0011) which was on par with VS-86 x TVM-3(0.0015).

4.1.22 Total phenols

The total phenol content ranged from 10.95 (Malika) to 11.20 (VS-86) in lines, 10.68 (TVM-3) to 11.38 (TVM-1) in testers and 10.37(P-1 x TVM-3) to 11.13 (Vellayani local x TVM-1, P-1 x TVM-1 and Malika x TVM-3) in hybrids

4.2 COMBINING ABILITY AND GENE ACTION

All the characters were subjected to line x tester analysis to study the gene action in terms of general combining ability and specific combining ability effects.

4.2.1 General Combining Ability Effects

The general combining ability effects of parents for 22 characters are presented in Table 6.

4.2.1.1 Days to 50% flowering

General combining ability effects of lines varied from –0.84 (VS-86) to 1.44 (P-1). The lines, P-1 (1.44) showed significant positive gca effect whereas, VS-86 (-0.84) had significant negative gca effect. Among the testers TVM-1
(-1.24) and TVM-3 (-0.44) showed significant negative gca effects where as KMV-1 (1.69) showed significant positive gca effect.

4.2.1.2 Length of harvest period(days)

General combining ability effects of lines varied from –1.85 (VS-86) to 1.32 (Vellayani local).The lines Vellayani local (1.32) which was on par with Malika (0.79) showed significant positive gca effect whereas Varuvila-2 (-0.56) and VS-86 (-1.85) showed significant negative gca effects. Among the testers TVM-1 (0.55) which was on par with TVM-3 (0.48) showed significant positive gca effects whereas KMV-1 (-1.03) showed significant negative gca effect.

4.2.1.3 Crop duration(days)

General combining ability effects of lines varied from –1.08 (VS-86) to 0.55 (Malika). The line Malika (0.55) showed significant positive gca effect whereas VS-86 (-1.08) showed significant negative gca effects. Among the testers KMV-1 (-0.67) which was on par with TVM-3 (-0.36) showed

Table 6. General combining ability effects of lines and testers

Characters / Treatments	Days to 50 per cent flowering	Length of harvest period (days)	Crop duration (days)	Primary branches per plant	Main stem length (cm)	Pod clusters per plant	Pods per plant	Pod yield per plant	Pods per clusters	Pod weight (g)	Pod length (cm)
Line											
Vellayani local	-0.44	1.32**	0.39	-0.04	15.57**	0.97**	2.89**	-21.72**	0.22	0.76**	-0.62
Varuvila-2	-0.47	-0.56**	-0.29	0.07	-16.59**	0.77**	1.45**	-11.09**	0.33	-1.24**	0.63
VS-86	-0.84**	-1.85**	-1.08**	0.11**	-21.89**	0.46**	1.32**	15.06**	0.19	-1.59**	-4.66**
P-1	1.44**	0.30	0.43	-0.11**	15.97**	-1.54**	-3.15**	22.64**	-0.38	1.54**	4.74**
Malika	0.31	0.79**	0.55**	-0.02	6.95**	-0.65**	-2.52**	-4.87**	-0.36	0.54**	-0.08
SE ±	0.27	0.25	0.24	0.05	0.76	0.05	0.05	0.95	0.34	0.19	0.34
CD	0.75	0.68	0.65	0.14	2.10	0.14	0.13	2.63	0.09	0.54	0.95
Testers											
TVM-1	-1.24**	0.55**	0.43**	0.05	3.82**	0.24	1.07	49.66	-0.07**	1.04**	0.75**
KMV-1	1.69**	-1.03**	-0.67**	-0.08**	-11.13**	-0.18	-0.62	-30.27	0.00	-1.29**	1.68**
TVM-3	-0.44**	0.48**	-0.36**	0.03	7.31**	-0.06	-0.45	-19.38	0.07**	0.26	-2.43**
SE ±	0.21	0.19	0.18	0.04	0.59	0.04	0.04	0.73	0.03	0.15	0.27
CD	0.58	0.53	0.51	0.11	1.63	0.11	0.11	2.03	0.07	0.42	0.74

Table 6. Continued

Characters / Treatments	Pod breadth (cm)	Seeds per pod	100 seed weight (g)	Root weight per plant (g)	Nodules per plant	Days to first harvest	Crude fibre content (%)	Protein content (g)	Peroxidase	Polyphenol oxidase	Total phenols
Line											
Vellayani local	-0.020**	1.84**	1.74**	-3.03**	0.89**	-0.05	0.002	-5.47**	-0.008	-0.0004**	-0.09
Varuvila-2	-0.010	-0.03	-1.88**	4.77**	-1.33**	-1.01**	0.042	5.87**	0.020**	-0.0005**	-0.01
VS-86	-0.060**	-0.89	1.34**	-0.12	1.49**	0.21**	-0.130**	-10.02**	0.015**	-0.0010**	0.02
P-1	-0.090**	-0.29	0.36**	-3.26**	-2.06**	0.99**	0.130**	6.09**	-0.030**	0.0012**	-0.08
Malika	0.050**	-0.61	-1.55**	1.64**	1.00**	-0.14**	-0.470**	3.53**	-0.005	0.0007**	0.16**
SE ±	0.010	0.63	0.11	0.21	0.15**	0.06	0.040	1.19	0.007	0.0001	0.05
CD	0.030	0.17	0.29	0.63	0.42	0.16	0.110	3.32	0.018	0.0002	0.16
Testers											
TVM-1	0.010	-1.72**	0.50	0.74**	-1.45**	-0.19**	0.030	-1.29	0.002	0.0000	0.18**
KMV-1	-0.010	1.48**	0.36	1.32**	0.62**	0.76**	-0.053	1.71	-0.006	0.0070**	0.03
TVM-3	0.002	0.24**	-0.86	-2.05**	0.83**	-0.57**	0.030	-0.42	0.004	-0.0007**	-0.21**
SE ±	0.010	0.05	0.08	0.16	0.12	0.04	0.030	0.93	0.005	0.0001	0.04
CD	0.020	0.14	0.23	0.46	0.33	0.12	0.080	2.57	0.014	0.0002	0.12

significant negative gca effects whereas TVM-1 (0.43) showed significant positive gca effect.

4.2.1.4 Primary branches per plant

General combining ability effects of lines varied from –0.11 (P-1) to 0.11 (VS-86). The line VS-86 (0.11) showed significant positive gca effects whereas P-1 (-0.11) showed significant negative gca effects. Among the testers, TVM-1 (0.05) and TVM-3 (0.03) showed positive gca effects whereas KMV-1 (-0.08) showed significant negative gca effects.

4.2.1.5 Main stem length(cm)

General combining ability effects of lines varied from –21.89 (VS-86) to 15.97 (P-1). The lines Vellayani local (15.57) which was on par with P-1 (15.97) showed significant positive gca effects whereas Varuvila-2 (-16.59) and VS-86 (-21.89) showed significant negative gca effects. Among the testers TVM-1 (3.82) and TVM-3 (7.31) showed significant positive gca effect whereas KMV-1 (-11.13) showed significant negative gca effect.

4.2.1.6 Pod clusters per plant

General combining ability effects of lines varied from –1.54 (P-1) to 0.97 (Vellayani local). The lines Vellayani local (0.97), Varuvila-2 (0.77) and VS-86 (0.46) showed significant positive gca effect whereas P-1 (-1.54) and Malika (-0.65) showed significant negative gca effect. Among the testers KMV-1 (-0.18) and TVM-3 (-0.06) showed negative gca effect whereas TVM-1 (0.24) showed positive gca effect.

4.2.1.7 Pods per plant

General combining ability effects of lines varied from –3.15 (P-1) to 2.89 (Vellayani local). The lines Vellayani local(2.89), Varuvila-2 (1.45) and VS-86 (1.32) showed significant positive gca effects whereas P-1 (-3.15) and Malika (-2.52) showed significant negative gca effects. Among the testers, KMV-1 (-0.62) and TVM-3 (-0.45) showed negative gca effects whereas TVM-1 (1.07) showed positive gca effect.

4.2.1.8 Pod yield per plant

General combining ability effects of lines varied from –21.72 (Vellayani local) to 22.64 (P-1). The lines VS-86 (15.06) and P-1 (22.64) showed significant positive gca effect whereas Vellayani local (-21.72), Varuvila-2 (-11.09) and Malika (-4.87) showed significant negative gca effect. Among testers KMV-1 (-30.27) and TVM-3 (-19.38) showed significant negative gca effect whereas TVM-1 (49.66) showed significant positive gca effect.

4.2.1.9 Pods per cluster

General combining ability effects of lines varied from –0.38 (P-1) to 0.33 (Varuvila-2). The lines Vellayani local (0.22), Varuvila-2 (0.33) and VS-86 (0.19) showed positive gca effects . P-1 (-0.38) which was on par with Malika (-0.36) showed negative gca effects, but none of the lines showed significant gca effect. Among testers, TVM-3 (0.07) showed significant positive gca effect whereas TVM-1 (-0.07) showed significant negative gca effect.

4.2.1.10 Pod weight (g)

General combining ability effects of lines varied from –1.59 (VS-86) to 1.54 (P-1). The lines Vellayani local (0.76), P-1 (1.54) and Malika (0.54) showed significant positive gca effect whereas Varuvila-2 (-1.24) which was on par with VS-86 (-1.59) showed significant negative gca effect. Among testers, TVM-1 (1.04) and KMV-1 (-1.29) showed significant positive and negative gca effect respectively.

4.2.1.11 Pod length(cm)

General combining ability of lines varied from –4.66 (VS-86) to 4.74 (P-1). The line P-1 (4.74) showed significant positive gca effect whereas VS-86 (-4.66) and showed negative gca effects. Among testers, TVM-1 (0.75) and KMV-1 (1.68) showed significant positive gca effects whereas TVM-3 (-2.43) showed significant negative gca effect.

4.2.1.12 Pod breadth(cm)

General combining ability of lines varied from –0.090 (P-1) to 0.050 (Malika). The lines Malika (0.050) showed significant positive gca effect whereas other lines Vellayani local (-0.020), VS-86 (-0.060) which was on par with P-1 (-0.090) showed significant negative gca effect. Among testers, TVM-1 (0.010) which was on par with TVM-3 (0.002) showed positive gca effect whereas KMV-1 (-0.010) showed negative gca effect.

4.2.1.13 Seeds per pod

General combining ability effects of lines ranged from –0.89 (VS-86) to 1.84 (Vellayani local). The lines Vellayani local (1.84) showed significant positive gca effect whereas Varuvila-2 (-0.03), VS-86 (-0.89), P-1 (-0.29) and Malika (-0.61) showed negative gca effects. Among testers, KMV-1 (1.48) and TVM-3 (0.24) showed significant positive gca effects, whereas TVM-1 (-0.72) showed significant negative gca effect.

4.2.1.14 100 seed weight(g)

General combining ability effects of lines varied from –1.88 (Varuvila-2) to 1.74 (Vellayani local). The lines Vellayani local (1.74), VS-86 (1.34) and P-1 (0.36) showed significant positive gca effects whereas Varuvila-2 (-1.88) and Malika (-1.55) showed significant negative gca effect. Among testers, TVM-1 (0.50) which was on par with KMV-1 (0.36) showed positive gca effect and TVM-3 (-0.86) showed negative gca effect.

4.2.1.15 Root weight per plant(g)

General combining ability effect of lines varied from –3.26 (P-1) to 4.77 (Varuvila-2). The lines, Varuvila-2 (4.77) and Malika (1.64) showed significant positive gca effect. Vellayani local(-3.03) which was on par with P-1 (-3.26) showed significant negative gca effect. Among testers, TVM-1 (0.74) and KMV-1 (1.32) showed significant positive gca effect whereas TVM-3 (-2.05) showed significant negative gca effect.

4.2.1.16 Nodules per plant

General combining ability of lines varied from –2.06 (P-1) to 1.49 (VS-86). The lines, Vellayani local (0.89), VS-86 (1.49) and Malika (1.00) showed significant positive gca effect whereas P-1 (-2.06) and Varuvila-2 (-1.33) showed significant negative gca effect. Among testers, KMV-1 (0.62) which was on par with TVM-3 (0.83) showed significant positive gca effect whereas TVM-1 (-1.45) showed significant negative gca effect.

4.2.1.17 Days to first harvest

General combining ability of lines varied from –1.01 (Varuvila-2) to 0.99 (P-1). The lines, Varuvila-2 (-1.01) and Malika (-0.14) showed significant negative gca effect whereas VS-86 (0.21) and P-1 (0.99) showed significant positive gca effect. Among testers,TVM-1 (-0.19) and TVM-3 (-0.57) showed significant negative gca effect whereas KMV-1 (0.76) showed significant positive gca effect.

4.2.1.18 Crude fibre content(%)

General combining ability of lines varied from –0.47 (Malika) to 0.13 (P-1). The line P-1 (0.13) showed significant positive gca effect whereas VS-86 (-0.13) and Malika (-0.47) showed significant negative gca effect. Among testers, TVM-1 and TVM-3 both having 0.03 showed positive gca effect whereas KMV-1 (-0.05) showed negative gca effect.

4.2.1.19 Protein content(g)

General combining ability of lines varied from –10.02 (VS-86) to 6.09 (P-1). The lines, Vellayani local(-5.47) and VS-86 (-10.02) showed significant negative gca effect whereas P-1 (6.09) which was on par with Varuvila-2 (5.87), and Malika (3.53) showed significant positive gca effects. Among testers, TVM-1 (-1.29) and TVM-3 (-0.42) showed negative gca effect whereas KMV-1 (1.71) showed positive gca effect.

4.2.1.20 Peroxidase

General combining ability of lines varied from –0.030 (P-1) to 0.020 (Varuvila-2). The lines, P-1 (-0.030) showed significant negative gca effect. Varuvila-2 (0.020) which was on par with VS-86 (0.015) showed significant positive gca effect. Among testers, TVM-1 (0.002) which was on par with TVM-3 (0.004) showed positive gca effect whereas KMV-1 (-0.006) showed negative gca effect.

4.2.1.21 Polyphenol oxidase

General combining ability of lines varied from –0.0010 (VS-86) to 0.0012 (P-1). The lines P-1 (0.0012) and Malika (0.0070) showed significant positive gca effect whereas Vellayani local (-0.0004), Varuvila-2 (-0.0005) and VS-86 (-0.0010) showed significant negative gca effect. Among testers, TVM-3 (-0.0007) showed significant negative gca effect whereas KMV-1 showed significant positive gca effect (0.0007).

4.2.1.22 Total phenols

General combining ability effect of lines varied from –0.09 (Vellayani local) to 0.16 (Malika). The lines Vellayani local(-0.09), Varuvila-2 (-0.01) and P-1 (-0.08) showed negative gca effect whereas Malika (0.16) showed significant positive gca effect. Among testers only TVM-3 (-0.21) showed significant negative gca effect, whereas TVM-1 (0.18) showed positive gca effect.

4.2.2 Specific Combining Ability Effects

The specific combining ability effects of hybrids for 22 characters are given in Table 7 and Fig 1.

4.2.2.1 Days to 50 % flowering

The specific combining ability varied from –1.24 (P-1 x TVM-3) to 2.13 (Varuvila-2 x TVM-3). Significant sca effects was shown by the crosses,

Table 7. Specific combining ability effects of hybrids

Characters / Treatments	Days to 50 per cent flowering	Length of harvest period (days)	Crop duration (days)	Primary branches per plant	Main stem length (cm)	Pod clusters per plant	Pods per plant	Pod yield per plant	Pods per clusters	Pod weight (g)	Pod length (cm)
Vellayani local x T_1	0.17	-2.39**	-0.20	0.06	5.47**	0.18**	2.53**	-11.08**	0.36**	-3.41**	-3.36**
Vellayani local x T_2	-0.09	2.18**	0.29	-0.08	2.08	-0.59**	-2.04**	15.52**	0.16**	0.05	-0.66
Vellayani local x T_3	-0.09	0.21	-0.08	0.02	-7.56**	0.42**	-0.48**	-4.44**	-0.51**	3.36**	2.69**
Varuvila-2 x T_1	-0.80	2.16**	-1.18**	-0.05	-8.31**	0.04	-3.43**	0.69	-0.42**	-0.41	0.33
Varuvila-2 x T_2	-1.33**	-0.99**	-1.22**	0.08	3.71	-0.06	2.80**	3.03	0.64**	-0.21	-0.99
Varuvila-2 x T_3	2.13**	-1.17**	2.40**	-0.03	4.60**	0.02	0.63**	-3.73**	-0.22**	0.63	-0.65
VS-86 x T_1	-0.49	-1.41**	0.39	0.04	-14.13**	-0.78**	-1.03**	21.21**	-0.02	1.88**	6.09**
VS-86 x T_2	1.24**	-0.31	-0.64	0.17	-3.05	0.72**	0.87**	-0.19	-0.56**	0.54	-2.29**
VS-86 x T_3	-0.75	1.72**	0.25	-0.20**	17.18**	0.06	0.16**	-21.02**	0.58**	-2.42**	-3.79**
P-1 x T_1	0.69	-0.84	-0.05	0.12	10.47**	0.49**	2.11**	-9.24**	0.16**	-2.72**	-7.31**
P-1 x T_2	0.56	0.14	1.44**	-0.14	1.08	0.05	-1.67**	-29.30**	-0.24**	-0.46	5.23**
P-1 x T_3	-1.24**	0.69	-1.39**	0.02	-11.56**	-0.54**	-0.44**	38.54**	0.09	3.18**	2.08**
Malika x T_1	0.42	2.47**	1.04**	-0.16	6.49**	0.07	-0.18**	-1.59	-0.07	4.68**	4.24**
Malika x T_2	-0.38	-1.02**	0.13	-0.03	-3.83	-0.11	0.04	10.94**	-0.00	0.08	-2.61**
Malika x T_3	-0.04	-1.46**	-1.17**	0.19**	-2.67	0.04	0.14	-9.35**	0.07	-4.75**	-1.64**
SE ±	0.47	0.43	0.41	0.09	1.31	0.08	0.08	1.64	0.06	0.34	0.59
CD	1.34	1.23	1.17	0.26	3.74	0.23	2.02	4.68	0.17	0.97	1.68

T_1 – TVM-1, T_2 – KMV-1, T_3 – TVM-3

Table 7. Continued

Characters / Treatments	Pod breadth (cm)	Seeds per pod	100 seed weight (g)	Root weight per plant (g)	Nodules per plant	Days to first harvest	Crude fibre content (%)	Protein content (g)	Peroxidase	Polyphenol oxidase	Total phenols
Vellayani local x T_1	-0.080**	-2.44**	1.08**	0.69	-4.04**	-0.280**	-0.110	-5.27**	0.005	-0.0005**	0.12
Vellayani local x T_2	-0.610**	0.76**	-2.18**	-2.76**	1.76**	-0.160	-0.106	-2.60	-0.007	0.0007**	-0.29**
Vellayani local x T_3	0.140**	1.67**	1.10**	2.07**	2.28**	0.440**	0.004	7.87**	0.001	-0.0002	0.18**
Varuvila-2 x T_1	0.030	-1.57**	-0.44**	-1.05**	-0.15	-0.320**	0.103	0.73	0.030**	-0.0000	0.01
Varuvila-2 x T_2	0.110**	0.49**	-0.36	1.51**	0.78**	-0.270**	-0.240**	-1.93	-0.005	-0.0002	0.09
Varuvila-2 x T_3	0.140**	1.07**	0.79**	-0.46	-0.63**	0.590**	0.134	1.20	-0.030**	0.0002	-0.10
VS-86 x T_1	-0.210**	3.43**	-0.32	7.78**	-1.71**	0.050	-0.016	-3.38	-0.030**	-0.0009**	-0.05
VS-86 x T_2	0.210**	-1.50**	1.09**	-8.34**	0.03	-0.090	0.054	5.29**	0.020**	0.0007**	0.13
VS-86 x T_3	0.190**	-1.93**	-0.76**	0.56	1.68**	0.040	-0.040	-1.91	0.008	0.0002	-0.08
P-1 x T_1	0.050**	-1.10**	2.72**	-2.93**	1.52**	0.410**	0.020	5.51**	-0.040**	0.0007**	0.11
P-1 x T_2	-0.050**	1.76**	-1.80**	4.46**	-2.62**	0.660**	0.070	1.51	0.010	-0.0004**	0.16
P-1 x T_3	-0.002	-0.66**	-0.92**	-1.50**	1.10**	-1.070**	-0.090	-7.02**	0.030**	-0.0003	-0.27**
Malika x T_1	-0.210**	1.68**	-3.04**	-4.46**	4.38**	0.140	0.002	2.40	0.030**	0.0008**	-0.19**
Malika x T_2	-0.030	-1.52**	3.24**	5.13**	0.05	-0.140	0.002	-2.27	-0.020**	-0.0009**	-0.07
Malika x T_3	-0.180**	-0.15	-0.21	-0.671	-4.43**	0.004	-0.004	-0.13	-0.010	0.0002	0.27**
SE ±	0.020	0.11	0.15	0.37	0.26	0.090	0.070	2.07	0.010	0.0002	0.09
CD	0.060	0.314	0.54	1.06	0.74	0.260	0.200	5.91	0.030	0.0005	0.26

T_1 – TVM-1, T_2 – KMV-1, T_3 – TVM-3

Varuvila-2 x KMV-1 (-1.33); Varuvila-2 x TVM-3 (2.13); VS-86 x KMV-1 (1.24) and P-1 x TVM-3 (-1.24).

4.2.2.2 Length of harvest period (days)

The specific combining ability varied from –2.39 (Vellayani x TVM-1) to 2.47 (Malika x TVM-1). Significant positive sca effects was shown by Vellayani local x KMV-1 (2.18); Varuvila-2 x TVM-1 (2.16); VS-86 x TVM-3 (1.72) and Malika x TVM-1 (2.47).

4.2.2.3 Crop duration (days)

The specific combining ability varied from –1.39 (P-1 x TVM-3) to 2.40 (Varuvila-2 x TVM-3). Significant positive sca effects was shown by crosses, Varuvila-2 x TVM-3 (2.40); P-1 x KMV-1 (1.44) and Malika x TVM-1 (1.04). Significant negative sca effects was shown by the crosses, Varuvila-2 x TVM-1 (-1.18); Varuvila-2 x KMV-1 (-1.22), P-1 x TVM-3 (-1.39) and Malika x TVM-3 (-1.17).

4.2.2.4 Primary branches per plant

The specific combining ability varied from –0.20 (VS-86 x TVM-3) to 0.19 (Malika x TVM-3). Significant positive sca effect was shown by Malika x TVM-3 (0.19) and significant negative sca effect was shown by VS-86 x TVM-3 (-0.20).

4.2.2.5 Main stem length (cm)

The specific combining ability varied from –14.13 (VS-86 x TVM-1) to 17.18 (VS-86 x TVM-3). Significant positive sca effect was shown by Vellayani local x TVM-1 (5.47), Varuvila-2 x TVM-3 (4.6); VS-86 x TVM-3 (17.18); P-1 x TVM-1 (10.47) and Malika x TVM-1 (6.49). Crosses, Vellayani local x TVM-3 (-7.56), Varuvila-2 x TVM-1 (-8.31); VS-86 x TVM-1 (-14.13) and P-1 x TVM-3 (-11.56) showed significant negative sca effect.

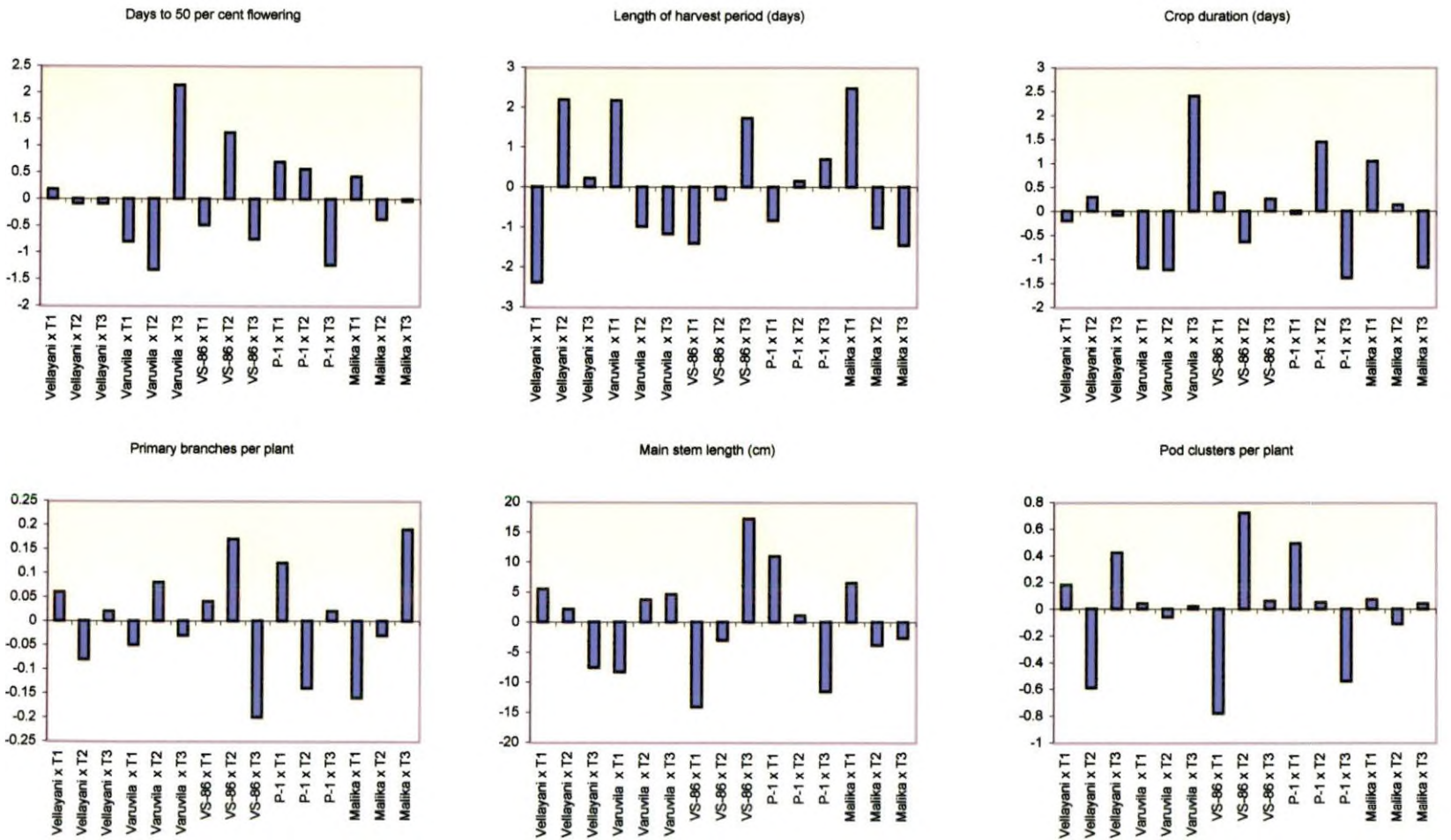


Fig. 1. Specific combining ability effects of hybrids

4.2.2.6 Pod clusters per plant

The specific combining ability varied from –0.78 (VS-86 x TVM-1) to 0.72 (VS-86 x KMV-1). Significant positive sca effect was shown by Vellayani local x TVM-1 (0.18); Vellayani local x TVM-3 (0.42); VS-86 x KMV-1 (0.72) and P-1 x TVM-1 (0.49). Significant negative sca effect was shown by Vellayani local x KMV-1 (-0.59); VS-86 x TVM-1 (-0.78) and P-1 x TVM-3 (-0.54).

4.2.2.7 Pods per plant

The specific combining ability varied from –3.43 (Varuvila-2 x TVM-1) to 2.80 (Varuvila-2 x KMV-1). The crosses, Vellayani local x TVM-1 (2.53); Varuvila-2 x KMV-1 (2.80); Varuvila-2 x TVM-3 (0.63), VS-86 x KMV-1 (0.87); VS-86 x TVM-3 (0.16); P-1 x TVM-1 (2.11). All other crosses except Malika x KMV-1 and Malika x TVM-3 showed negative sca effect.

4.2.2.8 Pod yield per plant

The specific combining ability varied from –29.30 (P-1 x KMV-1) to 38.54 (P-1 x TVM-3). Significant positive sca effect was shown by crosses, Vellayani localx KMV-1 (15.52), VS-86 x TVM-1 (21.21), P-1 x TVM-3 (38.54) and Malika x KMV-1 (10.94). All other crosses except Varuvila-2 x TVM-1, Varuvila-2 x KMV-1, VS-86 x KMV-1 and Malika x TVM-1 showed significant negative sca effect.

4.2.2.9 Pods per cluster

The specific combining ability varied from –0.56 (VS-86 x KMV-1) to 0.64 (Varuvila-2 x KMV-1). The crosses, Vellayani local x TVM-1 (0.36); Vellayani local x KMV-1 (0.16), Varuvila-2 x KMV-1 (0.64); VS-86 x TVM-3 (0.58); P-1 x TVM-1 (0.16) showed significant positive sca effects. Significant negative sca effects was shown by crosses, Vellayani local x TVM-3 (-0.51); Varuvila-2 x TVM-1 (-0.42); Varuvila-2 x TVM-3 (-0.22), VS-86 x KMV-1 (-0.56) and P-1 x KMV-1 (-0.24).

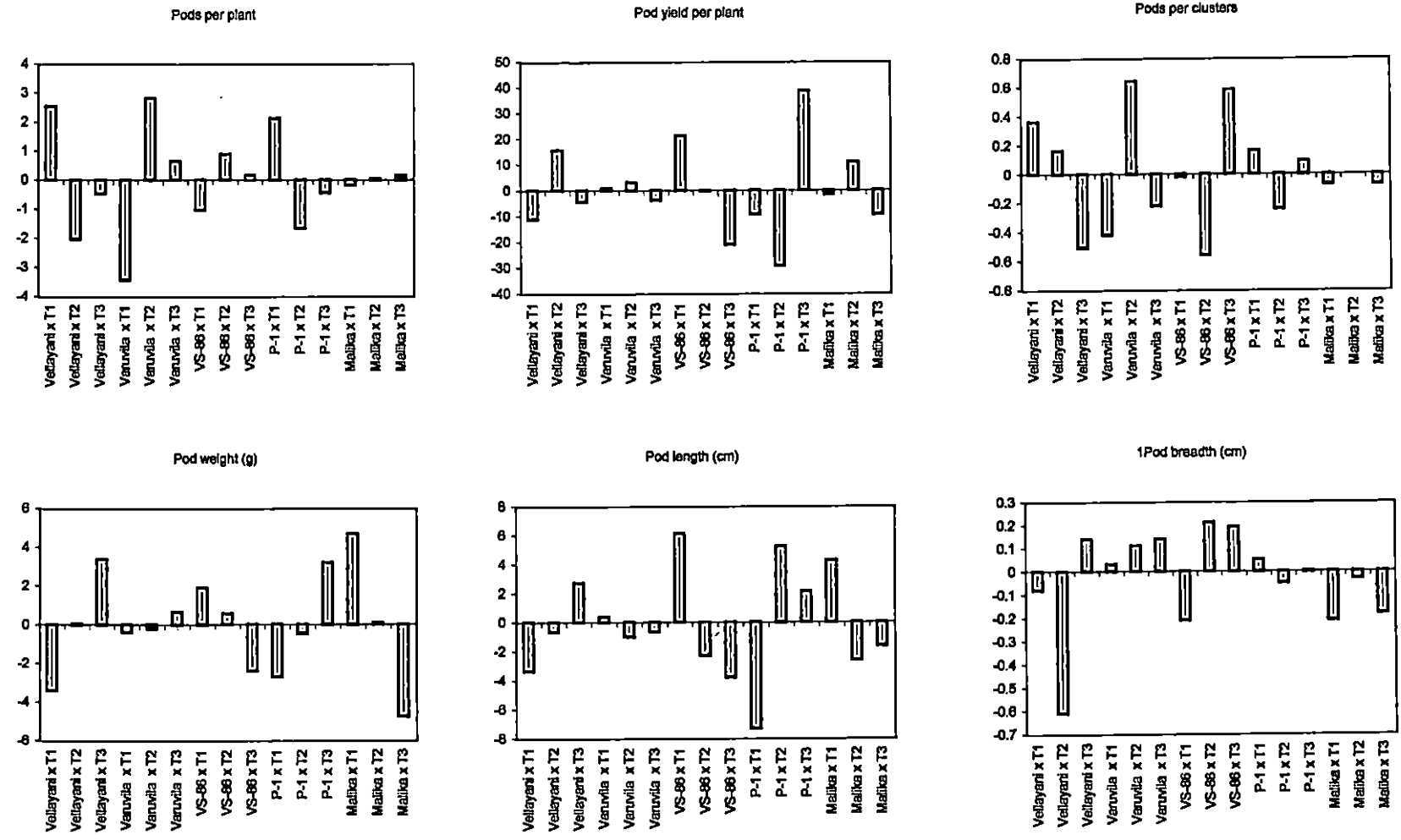


Fig. 1. Continued

4.2.2.10 Pod weight(g)

The specific combining ability values ranged from –4.75 (Malika x TVM-3) to 4.68 (Malika x TVM-1). The crosses, Vellayani local x TVM-3 (3.36), VS-86 x TVM-1 (1.88), P-1 x TVM-3 (3.18) and Malika x TVM-1 (4.68) showed significant positive sca effects. The crosses, Vellayani local x TVM-1 (-3.41); VS-86 x TVM-3 (-2.42), P-1 x TVM-1 (-2.72) and Malika x TVM-3 (-4.75) showed significant negative sca effects.

4.2.2.11 Pod length (cm)

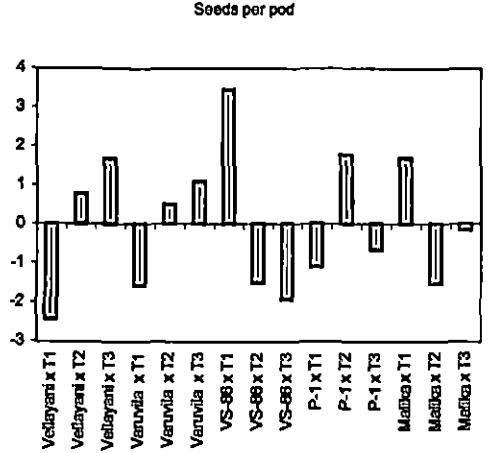
The specific combining ability values ranged from –7.31 (P-1 x TVM-1) to 6.09 (VS-86 x TVM-1). Significant positive sca effect was shown by crosses, Vellayani local x TVM-3 (2.69); VS-86 x TVM-1 (6.09); P-1 x KMV-1 (5.23); P-1 x TVM-3 (2.08) and Malika x TVM-1 (4.24). Significant negative sca effect was shown by Vellayani local x TVM-1 (-3.36), VS-86 x KMV-1 (-2.29); VS-86 x TVM-3 (-3.79); P-1 x TVM-1 (-7.31), Malika x KMV-1 (-2.61) and Malika x TVM-3 (-1.64).

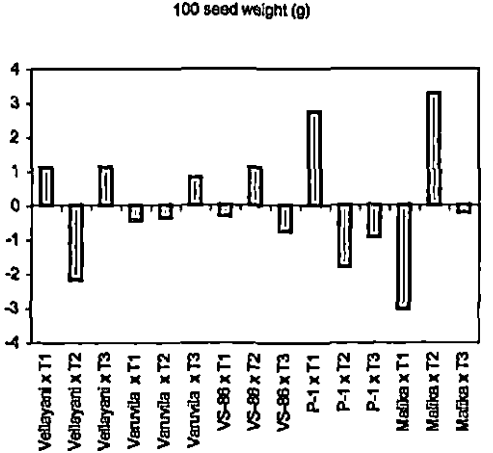
4.2.2.12 Pod breadth(cm)

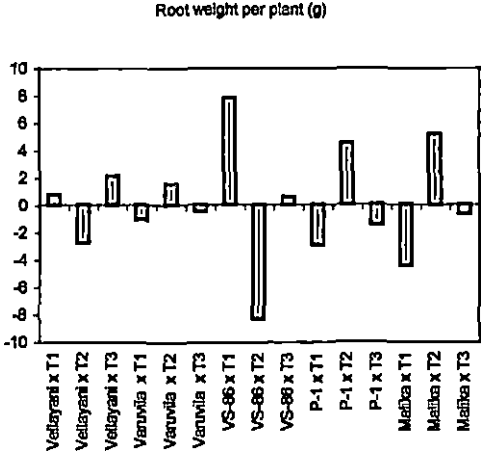
The specific combining ability values ranged from –0.61 (Vellayani local x KMV-1) to 0.21 (VS-86 x KMV-1). Significant positive sca effect was shown by crosses, Vellayani local x TVM-3 (0.14); Varuvila-2 x KMV-1 (0.11); Varuvila-2 x TVM-3(6.14); VS-86 x KMV-1 (0.21); VS-86 x TVM-3 (0.19); P-1 x TVM-1 (0.05). All other crosses except Varuvila-2 x TVM-1, P-1 x TVM-3 and Malika x KMV-1 showed significant negative sca effect.

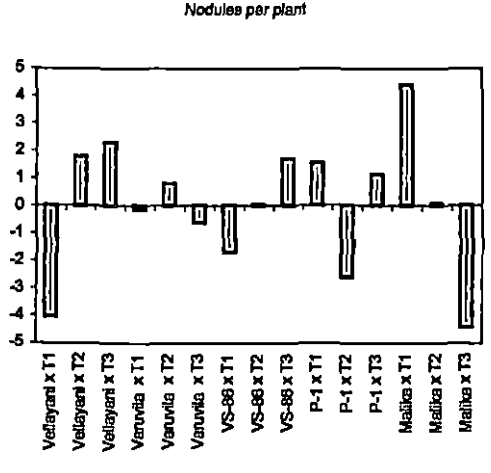
4.2.2.13 Seeds per pod

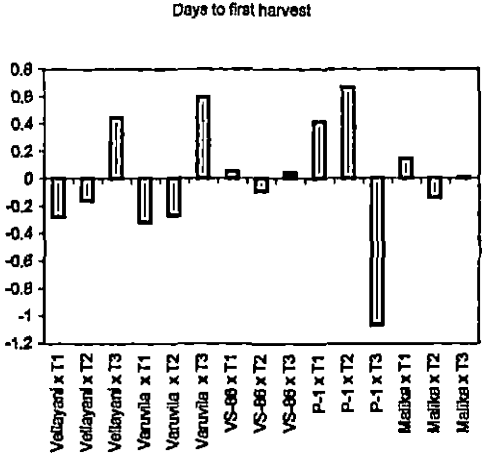
The specific combining ability values ranged from –2.44 (Vellayani local x TVM-1) to 3.43 (VS-86 x TVM-1). Significant positive sca effect was shown by crosses, Vellayani local x KMV-1 (0.76); Vellayani local x TVM-3 (1.67), Varuvila-2 x KMV-1 (0.49); Varuvila-2 x TVM-3 (1.07); VS-86 x TVM-1 (3.43); P-1 x KMV-1 (1.76) and Malika x TVM-1 (1.68). All other crosses, except Malika x TVM-3 (-0.15) showed significant negative sca effect.











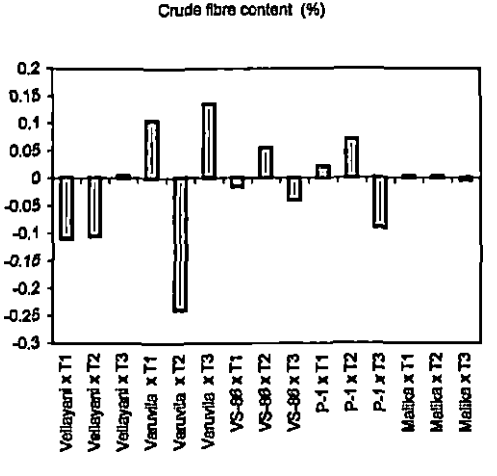


Fig. 1. Continued

4.2.2.14 100 seed weight(g)

The specific combining ability values varied from –3.04 (Malika x TVM-1) to 3.24 (Malika x KMV-1). Significant positive sca effect was shown by crosses, Vellayani local x TVM-1 (1.08); Vellayani local x TVM-3 (1.10); Varuvila-2 x TVM-3 (0.79); VS-86 x KMV-1 (1.09); P-1 x TVM-1 (2.72) and Malika x KMV-1 (3.24). The crosses, Vellayani local x KMV-1 (-2.18); Varuvila-2 x TVM-1 (-0.44); VS-86 x TVM-3 (-0.76); P-1 x KMV-1 (-1.80); P-1 x TVM-3 (-0.92) and Malika x TVM-1 (-3.04) showed significant negative sca effect.

4.2.2.15 Root weight per plant(g)

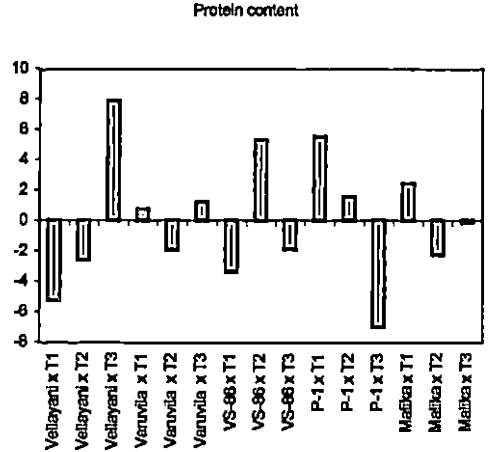
The specific combining ability values ranged from –8.34 (VS-86 x KMV-1) to 7.78 (VS-86 x TVM-1). The crosses, Vellayani local x TVM-3 (2.07);Varuvila-2 x KMV-1(1.51); VS-86 x TVM-1 (7.78); P-1 x KMV-1 (4.46) and Malika x KMV-1 (5.13) showed significant positive sca effect. Significant negative sca effect was shown by crosses, Vellayani local x KMV-1 (-2.76), Varuvila-2 x TVM-1 (-1.05), VS-86 x KMV-1 (-8.34), P-1 x TVM-1 (-2.93), P-1 x TVM-3 (-1.50) and Malika x TVM-1 (-4.46).

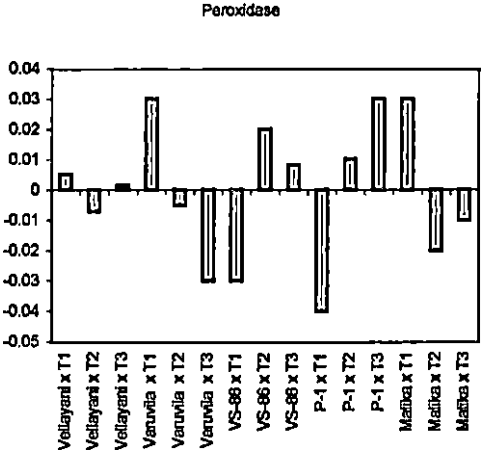
4.2.2.16 Nodules per plant

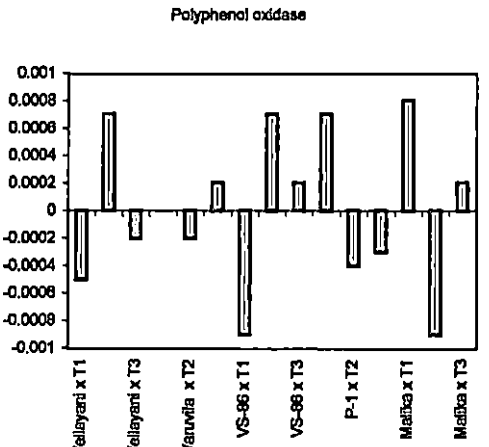
The specific combining ability values ranged from – 4.43 (Malika x TVM-3) to 4.38 (Malika x TVM-1). Significant positive sca effect was shown by crosses, Vellayani local x KMV-1(1.76);Vellayani local x TVM-3 (2.28); Varuvila-2 x KMV-1(0.78);VS-86 x TVM-3 (1.68); P-1 x TVM-1 (1.52); P-1 x TVM-3 (1.10) and Malika x TVM-1 (4.38). All other crosses except Varuvila-2 x TVM-1, VS-86 x KMV-1 and Malika x KMV-1 showed significant negative sca effect.

4.2.2.17 Days to first harvest

The specific combining ability values ranged from –1.07 (P-1 x TVM-3) to 0.66 (P-1 x KMV-1). Significant positive sca effect was shown by crosses, Vellayani local x TVM-3 (0.44), Varuvila-2 x TVM-3 (0.59), P-1 x TVM-1 (0.41), P-1 x KMV-1 (0.66). Significant negative sca effect was







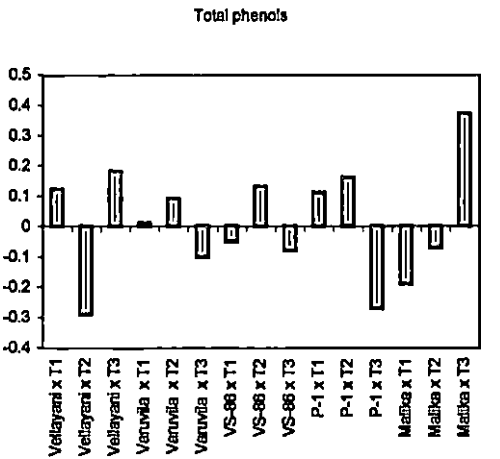


Fig. 1. Continued

shown by crosses, Vellayani local x TVM-1 (-0.28), Varuvila-2 x TVM-1 (-0.32); Varuvila-2 x KMV-1 (-0.27) and P-1 x TVM-3 (-1.07).

4.2.2.18 Crude fibre content (%)

The specific combining ability values ranged from -0.240 (Varuvila-2 x KMV-1) to 0.134(Varuvila-2 x TVM-3).Significant negative sca effect was shown by Varuvila-2 x KMV-1(-0.240).All other crosses showed non significant sca effect

4.2.2.19 Protein content(g)

The specific combining ability values ranged from –7.02 (P-1 x TVM-3) to 7.87 (Vellayani local x TVM-3). Significant positive sca effect was shown by Vellayani local x TVM-3 (7.87); VS-86 x KMV-1 (5.29) and P-1 x TVM-1 (5.51). The crosses, Vellayani local x TVM-1 (-5.27) and P-1 x TVM-3 (-7.02) showed significant negative sca effect.

4.2.2.20 Peroxidase

The specific combining ability values ranged from –0.04 (P-1 x TVM-1) to 0.03 (Malika x TVM-1, P-1 x TVM-3 and Varuvila-2 x TVM-1). Significant positive sca effect was shown by all crosses having sca value of 0.03 and VS-86 x KMV-1 (0.02).

4.2.2.21 Polyphenol oxidase

The specific combining ability value ranged from –0.0009 (VS-86 x TVM-1 and Malika x KMV-1) to 0.0008 (Malika x TVM-1). Significant positive sca effect was shown by crosses, Vellayani local x KMV-1 , VS-86 x KMV-1 and P-1 x TVM-1 with a value of 0.0007 and Malika x TVM-1 (0.0008). The crosses, Vellayani local x TVM-1 (-0.0005), VS-86 x TVM-1 (-0.0009), P-1 x KMV-1 (-0.0004) and Malika x KMV-1 (-0.0009) showed significant negative sca effect.

Table 8. Combination of parents for various characters based on specific combining ability effects

Testers / Lines	TVM-1	KMV-1	TVM-3
Vellayani	1. Length of harvest period 2. Crop duration 3. Primary branches / plant 4. Main stem length 5. Pods per plant 6. Pod/cluster 7. Days to first harvest 8. Crude fibre content 9. Peroxidase	Days to 50 per cent flowering Pod yield / plant Polyphenol oxidase	Days to 50 % flowering Pod cluster / plant Pod weight Pod length Pod breadth Seeds per pod 100 seed weight Root weight/plant Nodules per plant Crude protein content Total phenols
Varuvila-2	Pod cluster/plant Pod length Days to first harvest Peroxidase	Days to 50 % flowering Crop duration Primary branches/plant Pods per plant Pod yield/plant Pods/clusters Pod breadth Root weight/plant Nodules per plant Crude fibre content Total phenols	Length of harvest period Main stem length Pod weight Seeds/pod 100 seed weight Crude protein content Polyphenol oxidase
VS-86	Length of harvest period Pod yield/plant Pod weight Seeds/pod Root weight/plant	Crop duration Primary branches/plant Pod clusters/plant Pods/plant Pod breadth 100 seed weight Days to first harvest Crude protein content Peroxidase Polyphenol oxidase Total phenols	Days to 50 % flowering Main stem length Pods/clusters Nodules/plant Crude fibre content
P-1	Length of harvest period Primary branches per plant Main stem length Pod clusters per plant Pods per plant Pods per clusters Pod breadth 100 seed weight Nodules per plant Crude protein Poly phenol oxidase	Pod length Seeds per pod Root weight per plant Total phenols	Days to 50 % flowering Crop duration Pod yield per plant Pod weight Days to first harvest Crude fibre content Peroxidase
Malika	Main stem length Pod length Pod clusters per plant Pod weight Seeds per pod Nodules per plant Crude protein Peroxidase Polyphenol oxidase	Days to 50 % flowering Pod yield per plant Pod breadth 100 seed weight Root weight /plant Days to first harvest	Length of harvest period Crop duration Primary branches per plant Pods per plant Pods per cluster Crude fibre Total phenols

4.2.2.22 Total phenols

The specific combining ability value ranged from –0.29 (Vellayani local x KMV-1) to 0.27 (Malika x TVM-3). Significant positive sca effect was shown by crosses, Vellayani local x TVM-3 (0.18) and Malika x TVM-3 (0.27). The crosses, Vellayani local x KMV-1 (-0.29), P-1 x TVM-3(-0.27) and Malika x TVM-1 (-0.19) showed significant negative sca effect.

Combination of parents for various characters based on sca effects are given in Table 8.

4.3 COMPONENTS OF GENETIC VARIANCE

Dominance variance were high for all the characters. The ratio of additive variance to dominance variance was less than unity for all the characters. Components of genetic variance is given in the Table 9.

4.4 PROPORTIONAL CONTRIBUTION

The proportional contribution of lines, testers and crosses to total variance of the characters under study are presented in Table 10 and Fig 2.

The values ranged from 12.79 for total phenols to 86.37 for pod clusters per plant among lines. Among testers, the values ranged from 0.48 for pod breadth to 70.11 pod yield per plant. In the case of crosses, the values ranged from 13.67 pod clusters per plant to 81.11 for pod breadth.

The crosses had contributed maximum to the total variance for all characters except days to 50% flowering, main stem length, pod clusters per plant, pods per plant, pod yield per plant, days to first harvest , protein content and poly phenol oxidase activity. The testers had the least contribution to the total variance with respect to crosses and lines.

4.5 HETEROSIS

All the characters were subjected to line x tester analysis to study the Standard heterosis, Heterobeltiosis and Relative heterosis. The percentage of

Table 9. Components of Genetic Variance

Sl. No.	Characters	Additive variance	Dominance variance
1	Days to 50 per cent flowering	0.180	1.28
2	Length of harvest period (days)	0.010	3.95
3	Crop duration (days)	-0.030	1.82
4	Primary branches per plant	0.000	0.16
5	Main stem length (cm)	31.090	124.22
6	Pod clusters per plant	0.090	0.27
7	Pods per plant	0.480	5.00
8	Pod yield per plant	150.840	489.47
9	Pods per clusters	0.001	0.22
10	Pod weight (g)	-0.270	11.81
11	Pod length (cm)	0.290	23.38
12	Pod breadth (cm)	-0.001	0.03
13	Seeds per pod	0.070	5.09
14	100 seed weight (g)	0.050	5.11
15	Root weight per plant (g)	0.002	27.83
16	Nodules per plant	-0.110	10.00
17	Days to first harvest	0.070	0.32
18	Crude fibre content (%)	0.0003	0.11
19	Protein content (g)	3.690	25.44
20	Peroxidase	0.000	0.001
21	Polyphenol oxidase	0.000	0.00
22	Total phenols	0.002	0.04

Table 10. Proportional contribution of lines, testers and L x T to total variance

Sl. No.	Characters	Line (%)	Testers (%)	Line x Testers (%)
1	Days to 50 per cent flowering	22.09	51.14	26.76
2	Length of harvest period (days)	31.28	13.26	55.46
3	Crop duration (days)	24.43	6.81	68.88
4	Primary branches per plant	28.07	14.74	57.18
5	Main stem length (cm)	66.48	16.35	17.17
6	Pod clusters per plant	86.37	2.96	13.67
7	Pods per plant	63.70	6.46	29.83
8	Pod yield per plant	15.19	70.11	14.69
9	Pods per clusters	43.32	1.37	55.31
10	Pod weight (g)	16.69	10.74	72.56
11	Pod length (cm)	36.34	12.51	51.15
12	Pod breadth (cm)	18.41	0.48	81.11
13	Seeds per pod	17.22	32.23	50.56
14	100 seed weight (g)	41.14	7.01	51.85
15	Root weight per plant (g)	34.63	8.27	57.11
16	Nodules per plant	23.83	12.52	65.65
17	Days to first harvest	45.81	34.73	19.46
18	Crude fibre content (%)	43.22	8.22	48.56
19	Protein content (g)	71.06	2.634	26.31
20	Peroxidase	39.78	2.45	57.77
21	Polyphenol oxidase	53.85	22.67	23.48
22	Total phenols	12.79	42.94	44.26

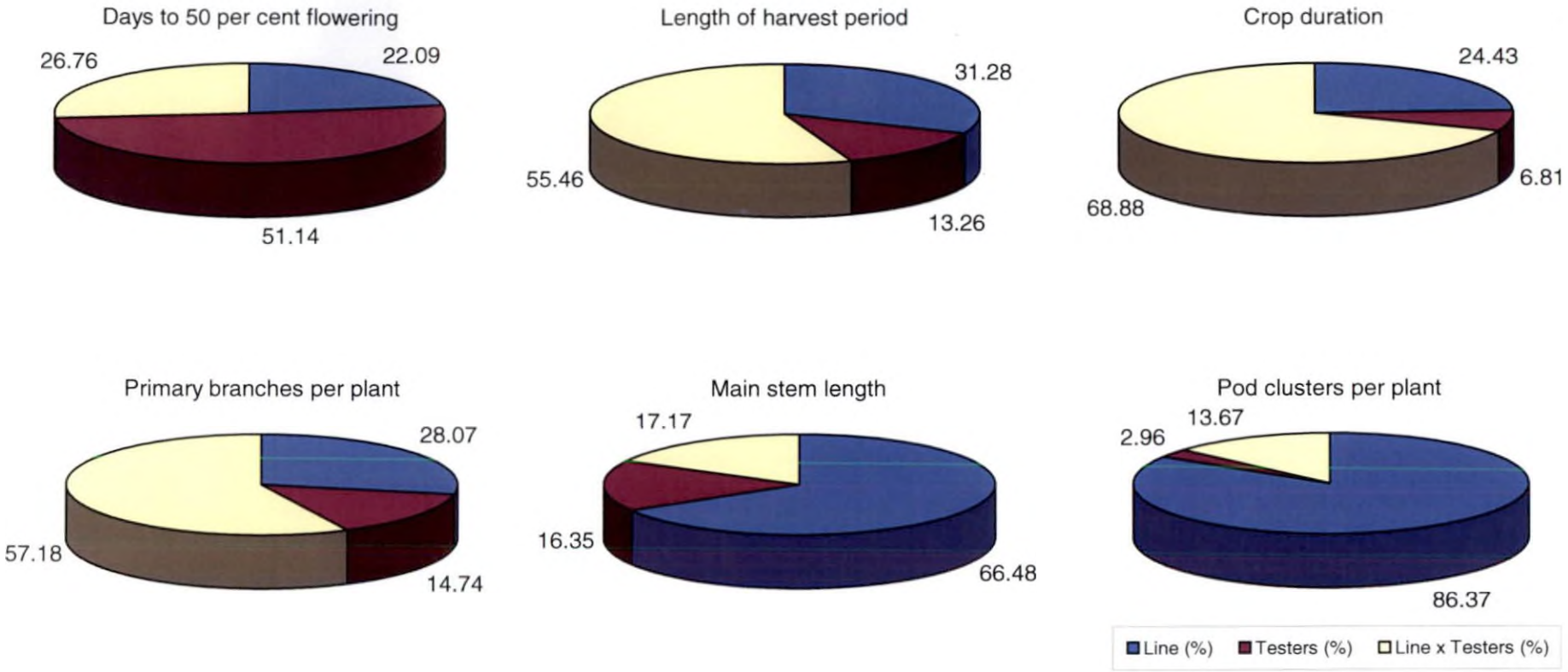
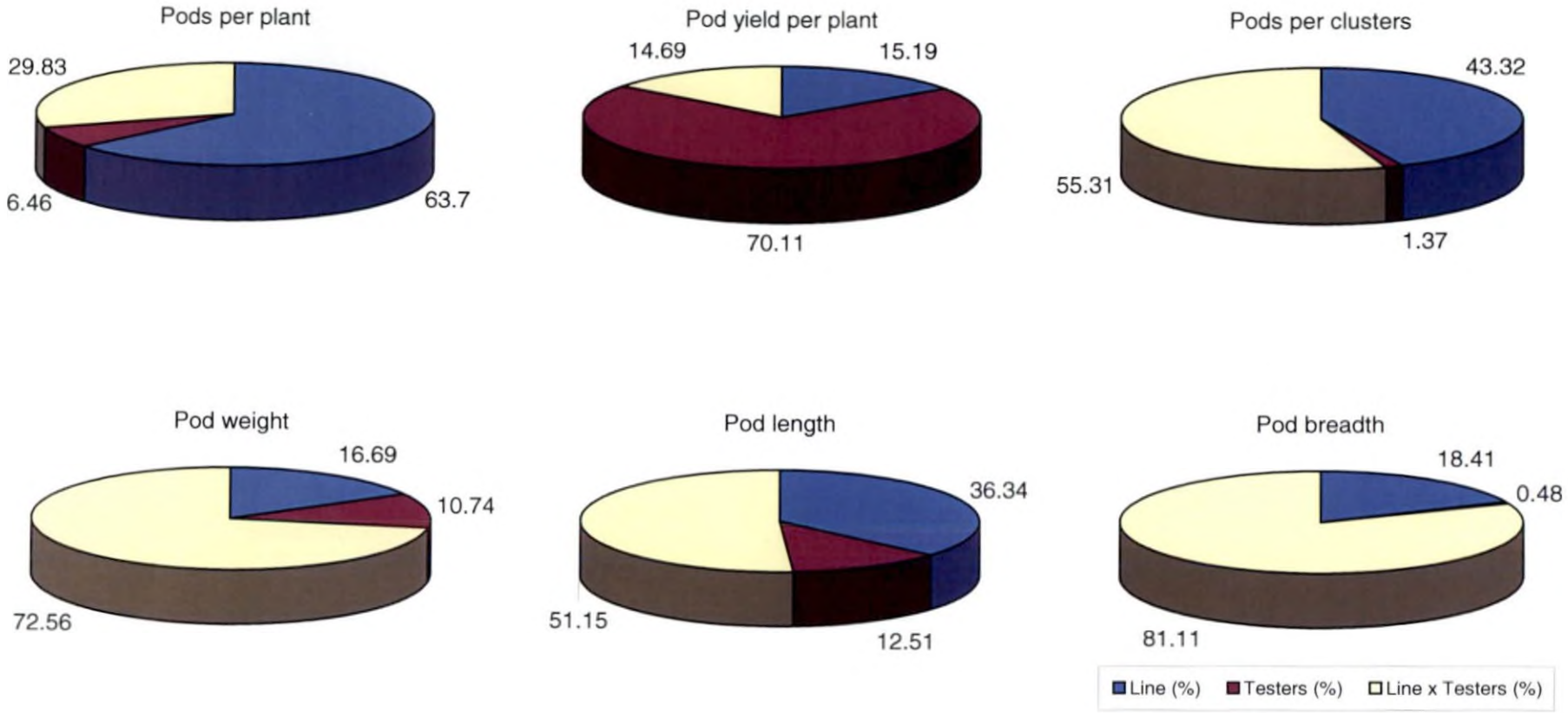


Fig. 2. Proportional contribution of lines, testers and line x tester to the total variance



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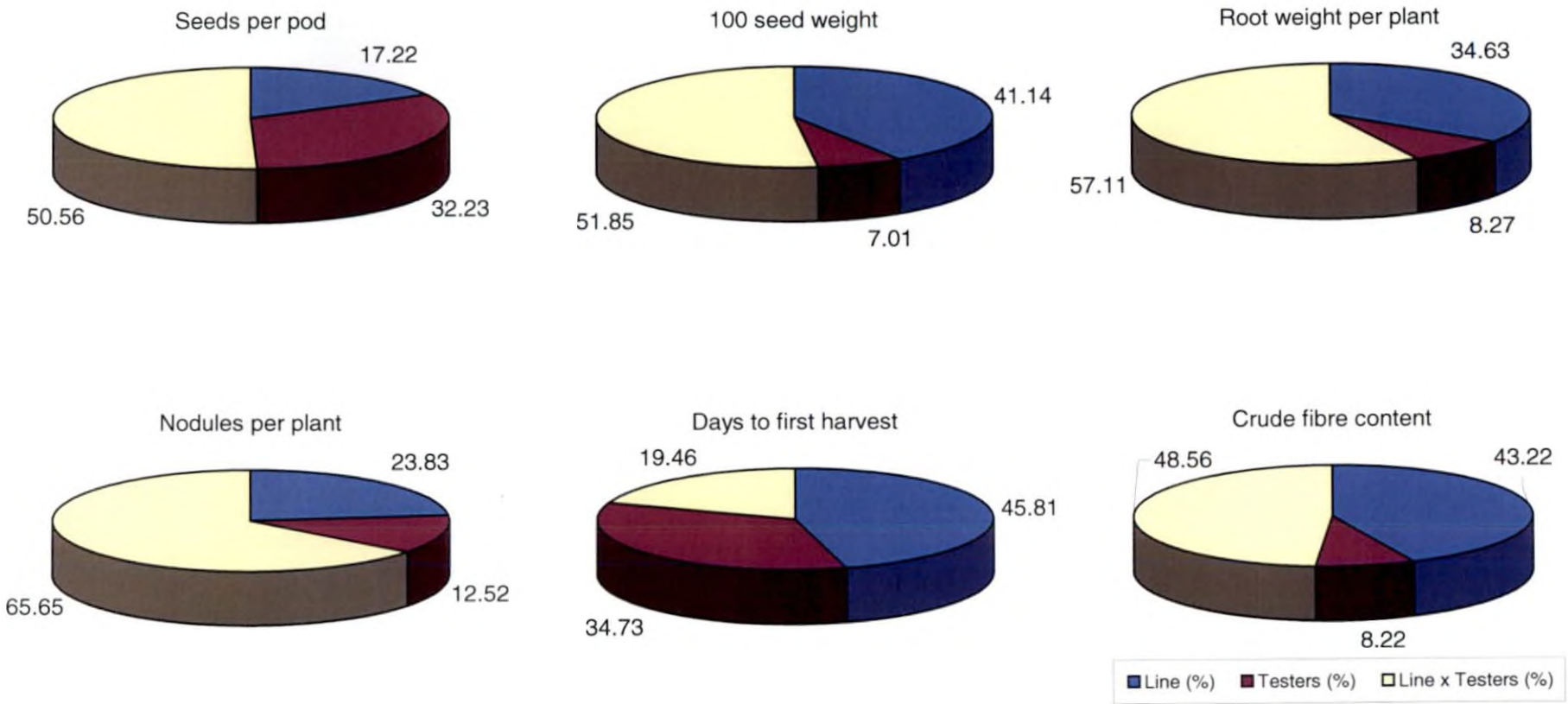

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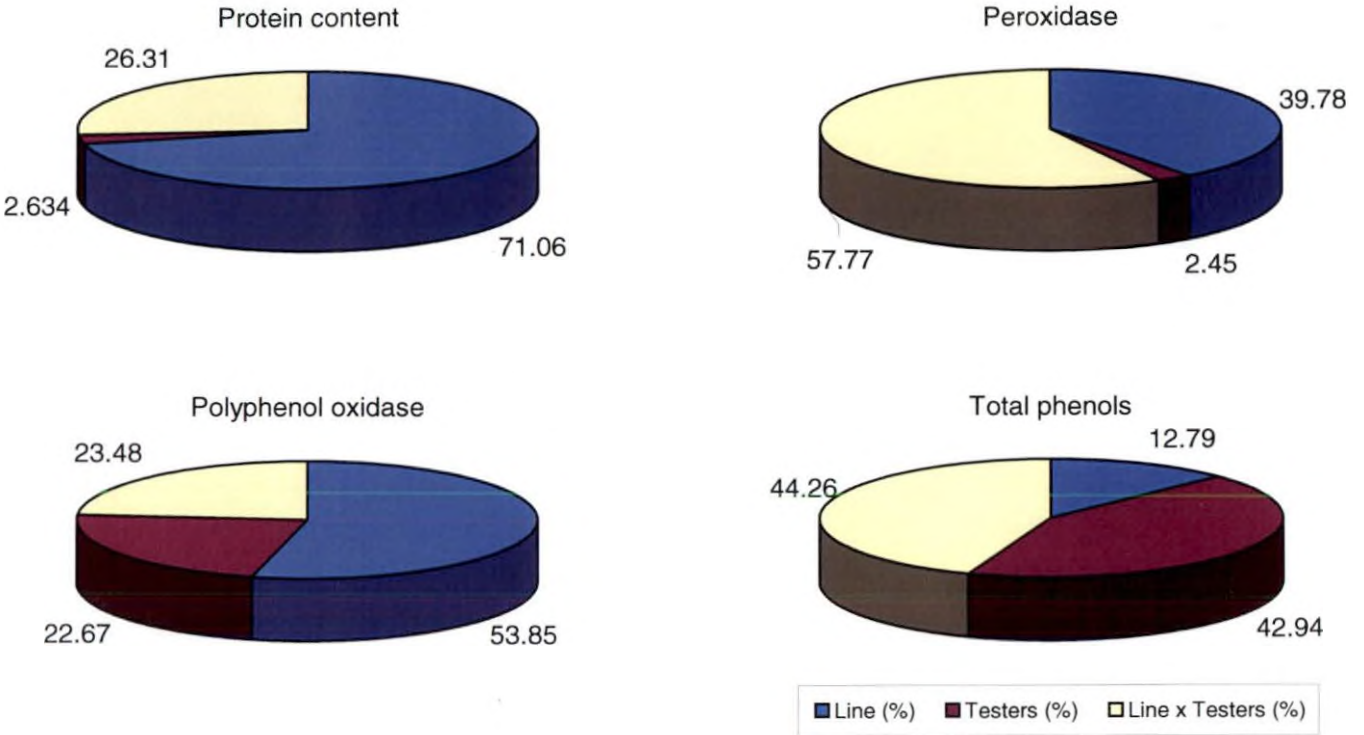


Fig. 2. Continued

heterosis of hybrids for different characters are presented in Table 11-32 and Fig 3.

4.5.1 Days to 50% flowering

The value of heterosis ranged from –7.07 (VS-86 x TVM-1) to 5.72 (P-1 x KMV-1) for standard heterosis, -5.29 (P-1 x TVM-3) to 5.27 (Varuvila-2 x TVM-3) for heterobeltiosis and –1.49 (VS-86 x TVM-1) to 5.95 (Varuvila-2 x TVM-3) for relative heterosis. Significant negative standard heterosis was shown by the crosses Vellayani local x TVM-1 (-4.90), Vellayani local x TVM-3 (-3.80), Varuvila-2 x TVM-1 (-6.95), VS-86 x TVM-1 (-7.07), VS-86 x TVM-3 (-5.98) and Malika x TVM-1 (-2.86). Significant negative heterobeltiosis was shown by crosses Varuvila-2 x KMV-1 (-4.27), P-1 x TVM-1 (-3.05), P-1 x TVM-3 (-5.29) and Malika x TVM-1 (-2.86). None of the crosses showed significant negative relative heterosis for days to 50 per cent flowering.

4.5.2 Length of harvest period (days)

The value of heterosis ranged from –22.38 (VS-86 x KMV-1) to –4.28 (Vellayani local x KMV-1) for standard heterosis, -23.54 (VS-86 x KMV-1) to 17.83 (Vellayani local x KMV-1) for heterobeltiosis and –15.59 (VS-86 x TVM-1) to 20.20 (Vellayani local x KMV-1) for relative heterosis. All the crosses showed significant negative standard heterosis except Malika x TVM-1.Significant negative heterobeltiosis was shown by crosses Varuvila-2 x KMV-1(-4.38), Varuvila-2 x TVM-1(-10.16),Varuvila-2 x TVM-3(-10.88), VS-86 x TVM-1(-22.06), VS-86 x KMV-1(-23.54), VS-86 x TVM-3(-12.38), P-1 x KMV-1(-5.42), Malika x KMV-1(-16.18) and Malika x TVM-3(-12.79). Significant negative relative heterosis was shown by crosses, Varuvila-2 x TVM-3(-5.42), VS-86 x TVM-1(-15.59), VS-86 x KMV-1(-13.5), VS-86 x TVM-3(-9.03), Malika x KMV-1(-5.86) and Malika x TVM-3(-10.12).

Table 11. Heterosis (%) for days to 50 per cent flowering

Characters	SH	HB	RH
Vellayani local x TVM-1	-4.90**	-1.83	0.13
Vellayani local x KMV-1	0.55	-1.72	0.96
Vellayani local x TVM-3	-3.80**	-0.69	0.57
Varuvila-2 x TVM-1	-6.95**	-2.71	-1.36
Varuvila-2 x KMV-1	-2.04	-4.27**	-1.03
Varuvila-2 x TVM-3	0.69	5.27**	5.95
VS-86 x TVM-1	-7.07**	-2.86	-1.49
VS-86 x KMV-1	2.45	0.12	3.51**
VS-86 x TVM-3	-5.98**	-1.72	-1.07
P-1 x TVM-1	0	-3.05**	1.93
P-1 x KMV-1	5.72	2.49	2.90
P-1 x TVM-3	-2.31	-5.29**	-1.09
Malika x TVM-1	-2.86**	-2.86**	0.63
Malika x KMV-1	1.52	-0.79	0.34
Malika x TVM-3	-2.66	-2.16	0.63
CD	1.35	1.35	1.17

Table 12. Heterosis(%) for length of harvest period

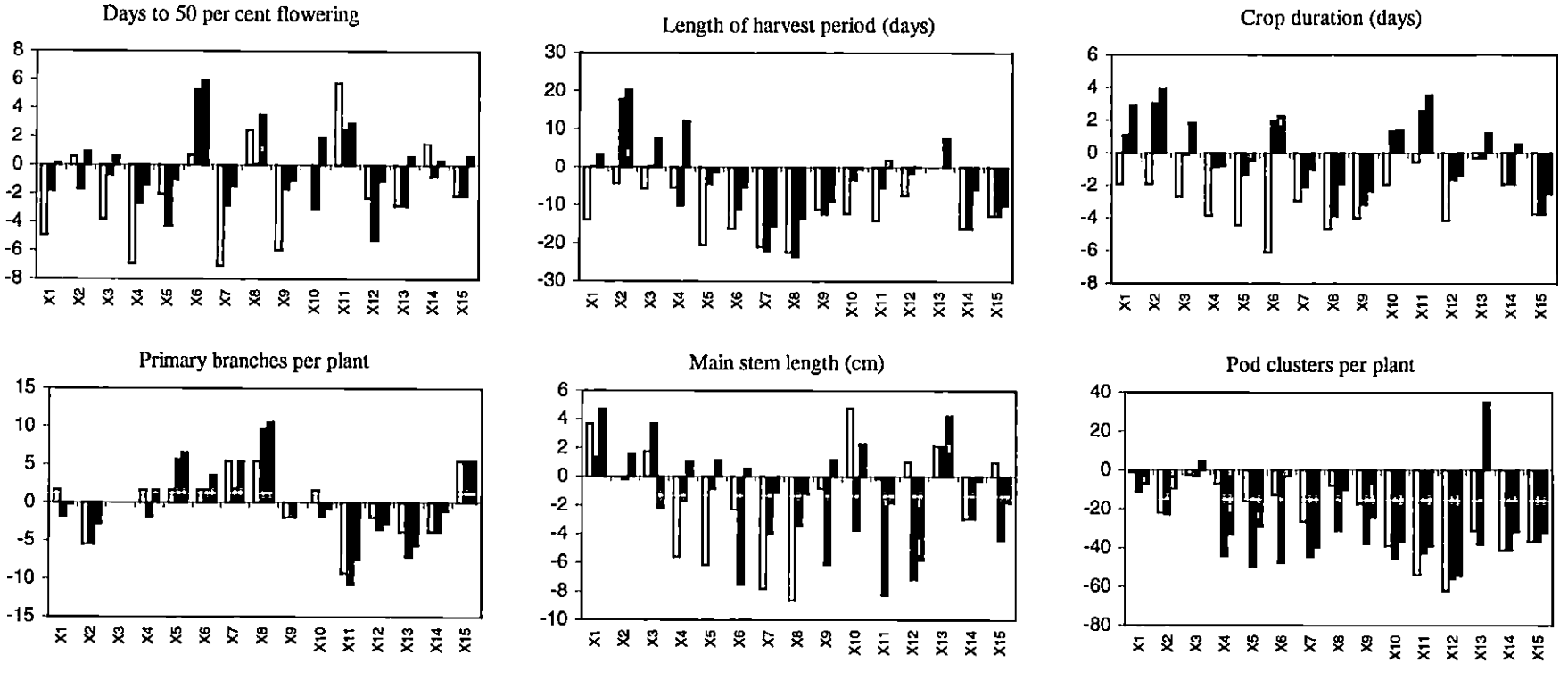
Characters	SH	HB	RH
Vellayani local x TVM-1	-13.88**	0.22	3.02
Vellayani local x KMV-1	-4.28**	17.83**	20.20**
Vellayani local x TVM-3	-5.76**	0.23	7.55**
Varuvila-2 x TVM-1	-5.34**	-10.16**	11.99**
Varuvila-2 x KMV-1	-20.47**	-4.38**	-1.31
Varuvila-2 x TVM-3	-16.21**	-10.88**	-5.41**
VS-86 x TVM-1	-20.91**	-22.06**	-15.59**
VS-86 x KMV-1	-22.38**	-23.54**	-13.51**
VS-86 x TVM-3	-11.09**	-12.38**	-9.031**
P-1 x TVM-1	-12.15**	-3.31	-0.61
P-1 x KMV-1	-14.07**	-5.42**	1.78
P-1 x TVM-3	-7.48**	-1.59	0.10
Malika x TVM-1	0	0	7.57**
Malika x KMV-1	-16.21**	-16.18**	-5.86**
Malika x TVM-3	-12.79**	-12.79**	-10.12**
CD	1.22	1.22	1.06

Table 13. Heterosis(%) for crop duration

Characters	SH	HB	RH
Vellayani local x TVM-1	-1.92**	1.10	2.89**
Vellayani local x KMV-1	-1.92**	3.05**	3.89**
Vellayani local x TVM-3	-2.67**	-0.15	1.84**
Varuvila-2 x TVM-1	-3.83**	-0.86	-0.79
Varuvila-2 x KMV-1	-4.44**	-1.34	-0.48
Varuvila-2 x TVM-3	-6.09**	1.97**	2.29**
VS-86 x TVM-1	-2.90**	-2.08**	-1.00
VS-86 x KMV-1	-4.67**	-3.87**	-1.89**
VS-86 x TVM-3	-3.98**	-3.17**	-2.33**
P-1 x TVM-1	-1.92**	1.33	1.38**
P-1 x KMV-1	-0.54	2.61	3.55**
P-1 x TVM-3	-4.13**	-1.65**	-1.37**
Malika x TVM-1	-0.31	-0.31	1.20**
Malika x KMV-1	-1.92**	-1.92**	0.50
Malika x TVM-3	-3.75**	-3.75**	-2.53**
CD	1.17	1.17	1.01

Table 14. Heterosis(%) for primary branches per plant

Characters	SH	HB	RH
Vellayani local x TVM-1	1.63	-1.84	-0.26
Vellayani local x KMV-1	-5.45	-5.45	-2.80
Vellayani local x TVM-3	0	0	0
Varuvila-2 x TVM-1	1.63	-1.84	1.63
Varuvila-2 x KMV-1	1.63	5.66	6.57
Varuvila-2 x TVM-3	1.63	1.63	3.61
VS-86 x TVM-1	5.45	1.84	5.45
VS-86 x KMV-1	5.45	9.63	10.57
VS-86 x TVM-3	-1.90	-1.90	0
P-1 x TVM-1	1.63	-1.84	-0.79
P-1 x KMV-1	-9.26	-10.72	-7.5
P-1 x TVM-3	-1.90	-3.48	-2.70
Malika x TVM-1	-3.81	-7.10	-5.61
Malika x KMV-1	-3.81	-3.81	-1.12
Malika x TVM-3	5.44	5.45	5.45
CD	0.82	0.82	0.71



X1	Vellayani x TVM-1	X6	Varuvila-2 x TVM-3	X11	P-1x KMV-1
X2	Vellayani x KMV-1	X7	VS-86x TVM-1	X12	P-1x TVM-3
X3	Vellayani x TVM-3	X8	VS-86x KMV-1	X13	Malika x TVM-1
X4	Varuvila-2 x TVM-1	X9	VS-86x TVM-3	X14	Malika x KMV-1
X5	Varuvila-2 x KMV-1	X10	P-1x TVM-1	X15	Malika x TVM-3

Fig. 3. Heterosis for various characters in 15 hybrids

4.5.3 Crop duration (days)

The value of heterosis ranged from –6.09 (Varuvila-2 x TVM-3) to –0.31 (Malika x TVM-1) for standard heterosis, -3.87(VS-86 x KMV-1) to 3.05(Vellayani local x KMV-1) for heterobeltiosis and -2.53(Malika x TVM-3) to 3.89 (Vellayani local x KMV-1) for relative heterosis. All crosses showed significant negative standard heterosis except P-1 x KMV-1 and Malika x TVM-1.Significant negative heterobeltiosis was shown by crosses, VS-86 x TVM-1(-2.08), VS-86 x KMV-1(-3.87), VS-86 x TVM-3(-3.17), P-1 x TVM-3 (-1.65), Malika x KMV-1(-1.92) and Malika x TVM-3(-3.75). Significant negative relative heterosis was shown by crosses, VS-86 x KMV-1(-1.89), VS-86 x TVM-3(-2.33), P-1 x TVM-3(-1.37) and Malika x TVM-3(-2.53).

4.5.4 Primary branches per plant

The value of heterosis ranged from –5.45 (Vellayani localx KMV-1) to 5.45 (VS-86 x TVM-1; VS-86 x KMV-1 and Malika x TVM-3) for standard heterosis, -10.72 (P-1 x KMV-1) to 9.63 (VS-86 x KMV-1) for heterobeltiosis and –5.61 (Malika x TVM-1) to 10.57 (VS86 x KMV-1) for relative heterosis. None of the crosses showed significant positive standard heterosis, heterobeltiosis and relative heterosis.

4.5.5 Main stem length(cm)

The value of heterosis ranged from –8.61 (VS-86 x KMV-1) to 4.76 (P-1 x TVM-1) for standard heterosis, -8.25 (P-1 x KMV-1) to 2.13 (Malika x TVM-1) for heterobeltiosis and –5.81 (P-1 x TVM-3) to 4.67 (Vellayani local x TVM-1) for relative heterosis. The crosses, Vellayani local x TVM-1 (3.67); Vellayani local x TVM-3 (1.75); P-1 x TVM-1 (4.76); P-1 x TVM-3 (1.02); Malika x TVM-1 (2.13) and Malika x TVM-3 (0.99) showed significant positive standard heterosis. The crosses, Vellayani local x TVM-1 (1.35) and Malika x TVM-1 (2.13) showed significant positive heterobeltiosis and Vellayani local x TVM-1 (4.67); Vellayani local x KMV-1 (1.54), Varuvila-2 x TVM-1 (1.04); Varuvila-2 x KMV-1 (1.16); VS-86 x TVM-3 (1.17); P-1 x

Table 15. Heterosis(%) for main stem length

Characters	SH	HB	RH
Vellayani local x TVM-1	3.67**	1.35**	4.67**
Vellayani local x KMV-1	-0.02	-0.21	1.54**
Vellayani local x TVM-3	1.75**	3.71**	-2.14**
Varuvila-2 x TVM-1	-5.59**	-1.68**	1.04**
Varuvila-2 x KMV-1	-6.18**	-0.85**	1.16**
Varuvila-2 x TVM-3	-2.28**	-7.53**	0.55
VS-86 x TVM-1	-7.83**	-4.01**	-1.11**
VS-86 x KMV-1	-8.61**	-3.42**	-1.20**
VS-86 x TVM-3	-0.82**	-6.14**	1.17**
P-1 x TVM-1	4.76**	-3.74**	2.29**
P-1 x KMV-1	-0.14	-8.25**	-1.84**
P-1 x TVM-3	1.02**	-7.17**	-5.81**
Malika x TVM-1	2.13**	2.13**	4.21**
Malika x KMV-1	-2.95	-2.95**	-0.27
Malika x TVM-3	0.99**	-4.42**	-1.79**
CD	3.75	3.75	3.25

Table 16. Heterosis(%) for pod clusters per plant

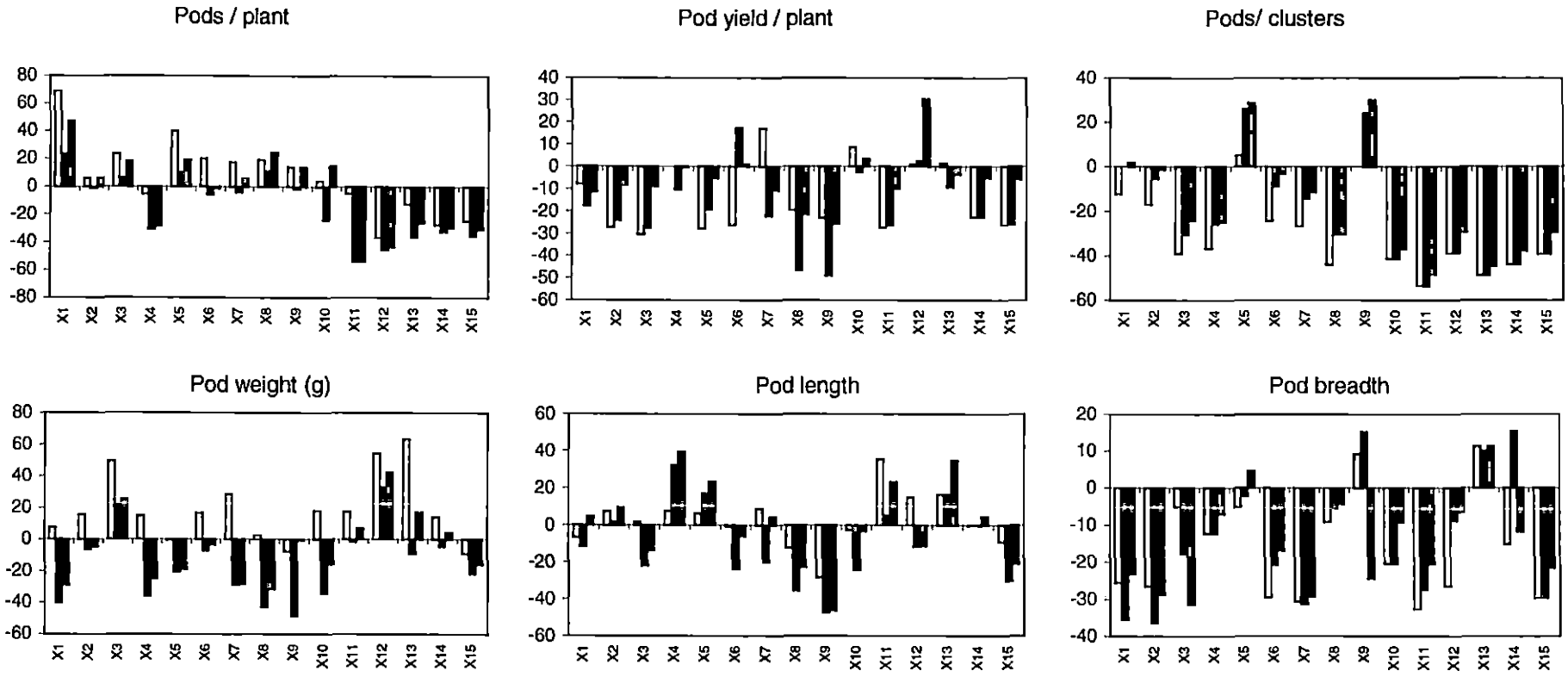
Characters	SH	HB	RH
Vellayani local x TVM-1	-1.21	-11.43**	-7.13**
Vellayani local x KMV-1	-21.89**	-22.82**	-9.40**
Vellayani local x TVM-3	-2.24**	-3.40**	4.42**
Varuvila-2 x TVM-1	-6.89**	-44.33**	-33.08**
Varuvila-2 x KMV-1	-16.06**	-49.79**	-29.42**
Varuvila-2 x TVM-3	-12.58**	-47.73**	-3.092**
VS-86 x TVM-1	-26.38**	-44.76**	-39.86**
VS-86 x KMV-1	-8.10**	-31.05**	-10.12**
VS-86 x TVM-3	-17.24**	-37.90**	-24.53
P-1 x TVM-1	-39.14**	-45.44**	-36.62**
P-1 x KMV-1	-53.96**	-42.83**	-39.32
P-1 x TVM-3	-62.07**	-56.00**	-54.49**
Malika x TVM-1	-31.03**	-38.17**	34.80**
Malika x KMV-1	-41.38**	-41.37**	-31.45**
Malika x TVM-3	-36.72**	-36.72	-32.04
CD	0.23	0.23	0.20

Table 17. Heterosis(%) for pods per plant

Characters	SH	HB	RH
Vellayani local x TVM-1	68.70**	23.41**	47.08**
Vellayani local x KMV-1	6.00**	-1.21	6.00**
Vellayani local x TVM-3	23.30**	6.29**	18.22**
Varuvila-2 x TVM-1	-5.30**	-30.72**	-28.26**
Varuvila-2 x KMV-1	40.00**	9.97**	19.35**
Varuvila-2 x TVM-3	20.00**	-5.73**	-1.31
VS-86 x TVM-1	17.30**	-4.19**	5.96
VS-86 x KMV-1	19.30**	11.18**	24.27**
VS-86 x TVM-3	14.00**	-1.72	13.66**
P-1 x TVM-1	4.00**	-23.92**	-14.75**
P-1 x KMV-1	-5.07**	-54.05**	-54.05**
P-1 x TVM-3	-36.70**	-45.43**	-43.33**
Malika x TVM-1	-12.70**	-36.14**	-26.20**
Malika x KMV-1	-27.30**	-32.25**	-29.20**
Malika x TVM-3	-24.70**	-35.09**	-30.27**
CD	0.23	0.23	0.20

Table 18. Heterosis(%) for pod yield per plant

Characters	SH	HB	RH
Vellayani local x TVM-1	-7.92**	-17.59**	-11.42**
Vellayani local x KMV-1	-27.19**	-24.29**	-8.35**
Vellayani local x TVM-3	-30.47**	-27.69**	-8.85**
Varuvila-2 x TVM-1	0.17	-10.35**	-0.39
Varuvila-2 x KMV-1	-27.86**	-19.32**	-5.15**
Varuvila-2 x TVM-3	-26.37**	-17.65**	0.99
VS-86 x TVM-1	17.03**	-22.09**	-10.65**
VS-86 x KMV-1	-19.58**	-46.46**	-21.46**
VS-86 x TVM-3	-23.17**	-48.85**	-25.63**
P-1 x TVM-1	8.77**	-2.65**	3.46**
P-1 x KMV-1	-27.36**	-26.27**	-9.90**
P-1 x TVM-3	1.08	2.59**	30.48**
Malika x TVM-1	1.59	-9.07**	-3.54**
Malika x KMV-1	-22.76**	-22.76**	-5.06**
Malika x TVM-3	-26.15**	-26.15**	-5.57
CD	4.69	4.69	4.06



X1	Vellayani x TVM-1	X6	Varuvila-2 x TVM-3	X11	P-1x KMV-1
X2	Vellayani x KMV-1	X7	VS-86x TVM-1	X12	P-1x TVM-3
X3	Vellayani x TVM-3	X8	VS-86x KMV-1	X13	Malika x TVM-1
X4	Varuvila-2 x TVM-1	X9	VS-86x TVM-3	X14	Malika x KMV-1
X5	Varuvila-2 x KMV-1	X10	P-1x TVM-1	X15	Malika x TVM-3

Fig. 3. Continued

TVM-1 (2.29) and Malika x TVM-1 (4.21) showed significant positive relative heterosis.

4.5.6 Pod clusters per plant

The value of heterosis ranged from –62.07 (P-1 x TVM-3) to –1.21 (Vellayani local x TVM-1) for standard heterosis, -56.00 (P-1 x TVM-3) to –3.40 (Vellayani local x TVM-3) for heterobeltiosis and –54.49 (P-1 x TVM-3) to 34.80 (Malika x TVM-1) for relative heterosis. All crosses showed significant negative standard heterosis and heterobeltiosis. The crosses, Vellayani local x TVM-3 (4.42) and Malika x TVM-1 (34.80) showed significant positive relative heterosis.

4.5.7 Pods per plant

The value of heterosis ranged from –36.70 (P-1 x TVM-3) to 68.70 (Vellayani local x TVM-1) for standard heterosis, -54.05 (P-1 x KMV-1) to 23.41 (Vellayani local x TVM-1) for heterobeltiosis and –54.05 (P-1 x KMV-1) to 47.08 (Vellayani local x TVM-1) for relative heterosis. Significant positive standard heterosis was shown by crosses, Vellayani local x TVM-1 (68.70); Vellayani local x KMV-1(6.00);Vellayani local x TVM-3 (23.30);Varuvila -2 x KMV-1(40.00);Varuvila -2 x TVM-3(20.00); VS-86 x TVM-1 (17.30); VS-86 x KMV-1 (19.30); VS-86 x TVM-3 (14.00); P-1 x TVM-1 (4.00). Significant positive heterobeltiosis was shown by crosses, Vellayani local x TVM-1 (23.41); Vellayani local x TVM-3 (6.29) and Varuvila-2 x KMV-1 (9.97).Significant positive relative heterosis was shown by crosses, Vellayani local x TVM-1 (47.08); Vellayani local x KMV-1 (6.00); Vellayani local x TVM-3 (18.22); Varuvila-2 x KMV-1 (19.35); VS-86 x TVM-1 (5.96); VS-86 x KMV-1 (24.27) and VS-86 x TVM-1 (13.66).

4.5.8 Pod yield per plant

The value of heterosis ranged from -30.47 (Vellayani local x TVM-3) to 17.03 (VS-86 x TVM-1) for standard heterosis, -48.85 (VS-86 x TVM-3) to 2.59 (P-1 x TVM-3) for heterobeltiosis and –25.63(VS-86 x TVM-3) to

Table 19. Heterosis(%) for pods per clusters

Characters	SH	HB	RH
Vellayani local x TVM-1	-12.08**	0	1.69
Vellayani local x KMV-1	-16.85**	-5.41	-1.30
Vellayani local x TVM-3	-38.82**	-30.41**	-24.09**
Varuvila-2 x TVM-1	-36.63**	-25.75**	-24.78**
Varuvila-2 x KMV-1	5.13	25.99**	28.69**
Varuvila-2 x TVM-3	-24.17**	-8.81**	-3.04
VS-86 x TVM-1	-26.74**	-14.16**	-11.50**
VS-86 x KMV-1	-43.95**	-30.45**	-30.45**
VS-86 x TVM-3	0	24.09**	30.00**
P-1 x TVM-1	-41.39**	-41.39**	-36.76**
P-1 x KMV-1	-53.48**	-53.85**	-48.37**
P-1 x TVM-3	-38.83**	-38.83**	-29.24**
Malika x TVM-1	-48.71**	-48.72**	-44.66**
Malika x KMV-1	-43.95**	-43.95**	-37.80**
Malika x TVM-3	-39.19**	-39.19**	-29.24**
CD	0.16	0.16	0.14

Table 20. Heterosis(%) for pod weight

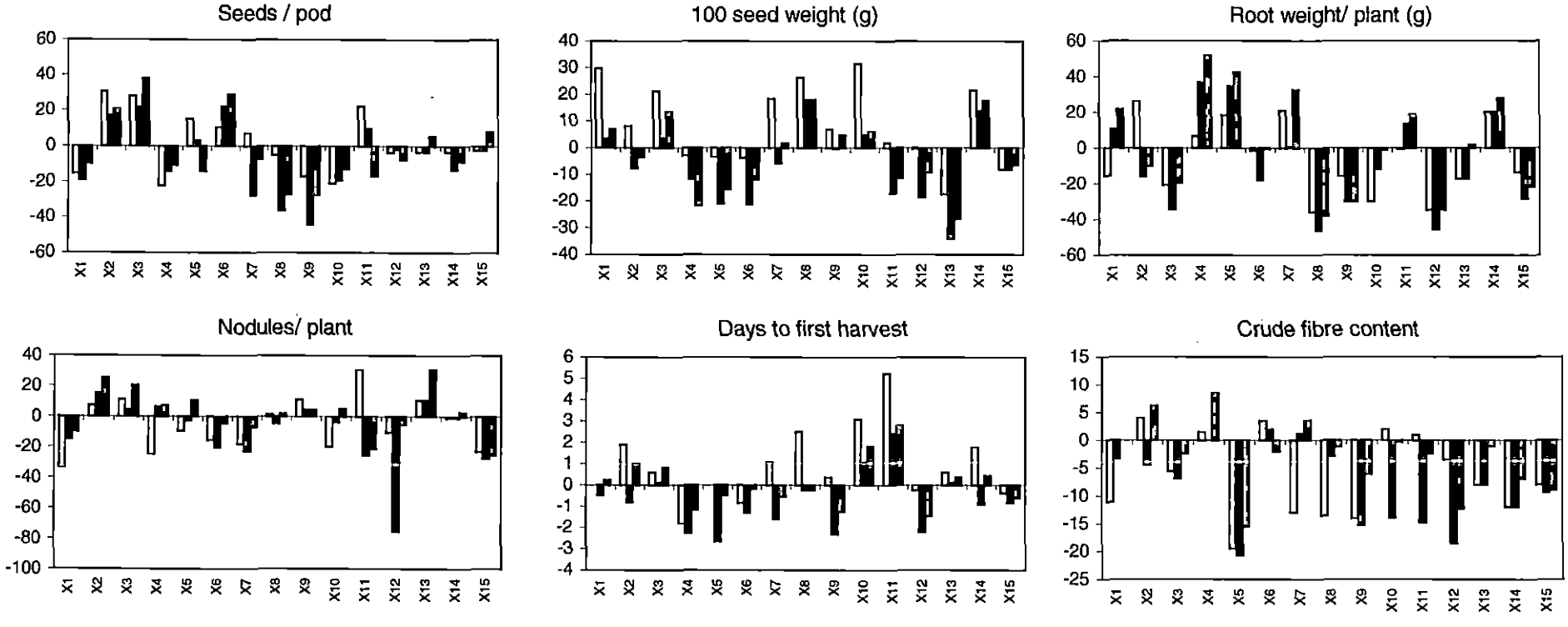
Characters	SH	HB	RH
Vellayani local x TVM-1	7.57**	-39.99**	-28.84**
Vellayani local x KMV-1	15.57**	-6.15**	-4.67
Vellayani local x TVM-3	49.33**	21.84**	25.44**
Varuvila-2 x TVM-1	14.64**	-36.04**	-24.75**
Varuvila-2 x KMV-1	-0.49	-20.64**	-18.67**
Varuvila-2 x TVM-3	16.56**	-7.10**	-3.46
VS-86 x TVM-1	28.31**	-28.42**	-28.34**
VS-86 x KMV-1	2.40	-42.73**	-31.32**
VS-86 x TVM-3	-7.50**	-48.28**	-0.37
P-1 x TVM-1	17.97**	-34.19**	-15.64
P-1 x KMV-1	17.48**	-1.60	6.89**
P-1 x TVM-3	54.28**	32.92**	42.48**
Malika x TVM-1	63.26**	-8.92**	16.93**
Malika x KMV-1	14.15**	-4.33	4.06
Malika x TVM-3	-8.92	-21.52**	-15.72**
CD	0.96	0.96	0.83

Table 21. Heterosis(%) for pod length

Characters	SH	HB	RH
Vellayani local x TVM-1	-6.59**	-11.46**	4.76**
Vellayani local x KMV-1	7.36**	1.77	9.31**
Vellayani local x TVM-3	1.53	-21.90**	-13.77**
Varuvila-2 x TVM-1	7.36**	32.37**	39.44**
Varuvila-2 x KMV-1	6.22**	16.81**	23.45**
Varuvila-2 x TVM-3	-0.73	-23.64**	-5.98**
VS-86 x TVM-1	8.69**	-20.00**	4.17**
VS-86 x KMV-1	-12.45	-35.56**	-22.79**
VS-86 x TVM-3	-28.30**	-47.24**	-46.06**
P-1 x TVM-1	-2.63	-24.33**	-3.37
P-1 x KMV-1	35.49**	5.30**	23.35**
P-1 x TVM-3	14.92**	-11.60**	-11.16**
Malika x TVM-1	16.41**	16.41**	34.72**
Malika x KMV-1	-0.36	-0.36	4.36
Malika x TVM-3	-9.23**	-30.17**	-21.07**
CD	1.69	1.69	1.47

Table 22. Heterosis(%) for pod breadth

Characters	SH	HB	RH
Vellayani local x TVM-1	-25.51**	-35.36**	-23.19**
Vellayani local x KMV-1	-26.53**	-36.28**	-28.71**
Vellayani local x TVM-3	-5.10	-17.69**	-31.25**
Varuvila-2 x TVM-1	-12.24**	-12.24**	-7.03**
Varuvila-2 x KMV-1	-5.10	-2.19	4.49
Varuvila-2 x TVM-3	-29.59**	-20.68**	-16.87**
VS-86 x TVM-1	-30.61**	-31.31**	-29.17**
VS-86 x KMV-1	-9.18**	-5.37	-4.35
VS-86 x TVM-3	9.18**	15.05**	-24.42**
P-1 x TVM-1	-20.41**	-20.41**	-9.30**
P-1 x KMV-1	-32.65**	-27.47**	-20.48**
P-1 x TVM-3	-26.53**	-8.86**	-6.49**
Malika x TVM-1	11.22**	10.10**	11.22**
Malika x KMV-1	-15.31**	15.31**	-11.70**
Malika x TVM-3	-29.59**	-29.59**	-21.59**
CD	0.05	0.05	0.04



X1	Vellayani x TVM-1	X6	Varuvila-2 x TVM-3	X11	P-1x KMV-1
X2	Vellayani x KMV-1	X7	VS-86x TVM-1	X12	P-1x TVM-3
X3	Vellayani x TVM-3	X8	VS-86x KMV-1	X13	Malika x TVM-1
X4	Varuvila-2 x TVM-1	X9	VS-86x TVM-3	X14	Malika x KMV-1
X5	Varuvila-2 x KMV-1	X10	P-1x TVM-1	X15	Malika x TVM-3

Fig. 3. Continued

30.48(P-1 x TVM-3) for relative heterosis.The crosses, VS-86 x TVM-1(17.03) and P-1 x TVM-1(8.77) showed significant positive standard heterosis. Positive standard heterobeltiosis was shown by P-1 x TVM-3(2.59). The crosses, P-1 x TVM-1(3.46) and P-1 x TVM-3(30.48) showed significant positive relative heterosis.

4.5.9 Pods per cluster

The value of heterosis ranged from -53.48 (P-1 x KMV-1) to 5.13 (Varuvila-2 x KMV-1) for standard heterosis, -53.85 (P-1 x KMV-1) to 25.99 (Varuvila-2 x KMV-1) for heterobeltiosis and -48.37 (P-1 x KMV-1) to 30.00(VS-86 x TVM-3) for relative heterosis. None of the crosses showed significant positive standard heterosis. Significant positive relative heterosis and heterobeltiosis were shown by Varuvila-2 x KMV-1(25.99 and 28.69 respectively) and VS-86 x TVM-3 (24.09 and 30.00 respectively)

4.5.10 Pod weight(g)

The value of heterosis ranged from –8.92 (Malika x TVM-3) to 63.26 (Malika x TVM-1) for standard heterosis; -48.28 (VS-86 x TVM-3) to 32.92 (P-1 x TVM-3) for heterobeltiosis and –31.32 (VS-86 x KMV-1) to 42.48 (P-1 x TVM-3) for relative heterosis. All crosses except Varuvila-2 x KMV-1, VS-86 x KMV-1; VS-86 x TVM-3 and Malika x TVM-3 showed significant positive standard heterosis. The crosses, Vellayani local x TVM-3 (21.83) and P-1 x TVM-3 (32.92) showed significant positive heterobeltiosis. Significant positive relative heterosis was shown by crosses, Vellayani local x TVM-3 (25.44), P-1 x KMV-1 (6.89); P-1 x TVM-3 (42.48) and Malika x TVM-1 (16.93).

4.5.11 Pod length (cm)

The value for heterosis ranged from –28.30 (VS-86 x TVM-3) to 35.49 (P-1 x KMV-1) for standard heterosis; -47.24 (VS-86 x TVM-3) to 32.37 (Varuvila-2 x TVM-1) for heterobeltiosis and –46.06 (VS-86 x TVM-3) to 39.44 (Varuvila-2 x TVM-1) for relative heterosis. Significant positive

Table 23. Heterosis(%) for seeds per pod

Characters	SH	HB	RH
Vellayani local x TVM-1	-15.28**	-19.09**	-9.94**
Vellayani local x KMV-1	30.50**	17.11**	20.75**
Vellayani local x TVM-3	28.07**	22.22**	38.24**
Varuvila-2 x TVM-1	-22.36**	-14.20**	-10.76**
Varuvila-2 x KMV-1	15.21**	3.39	-14.15**
Varuvila-2 x TVM-3	10.50**	22.09**	29.24**
VS-86 x TVM-1	7.14**	-27.88**	-7.58**
VS-86 x KMV-1	-5.21**	-36.20**	-27.09**
VS-86 x TVM-3	-17.14**	-44.23**	-27.63**
P-1 x TVM-1	-20.93**	-19.37**	-12.83**
P-1 x KMV-1	22.36**	9.80**	-16.77**
P-1 x TVM-3	-3.78	-1.89	-7.76**
Malika x TVM-1	-3.35	-3.35	5.45
Malika x KMV-1	-3.35	-13.27**	-8.58**
Malika x TVM-3	-2.35	-2.35	8.15**
CD	1.003	1.003	0.87

Table 24. Heterosis(%) for 100 seed weight

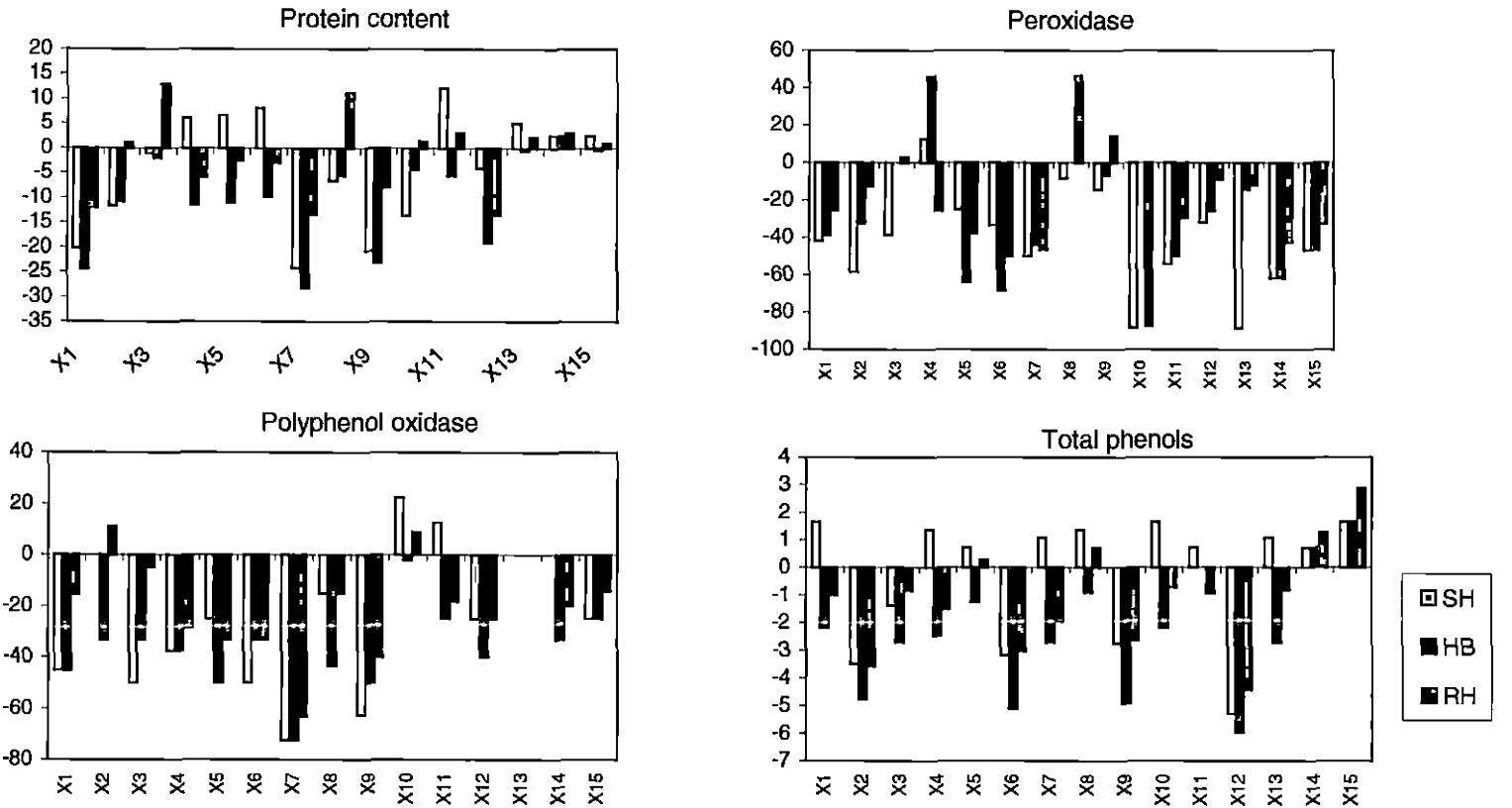
Characters	SH	HB	RH
Vellayani local x TVM-1	29.69**	3.39**	7.03**
Vellayani local x KMV-1	8.07**	-7.61**	-3.41**
Vellayani local x TVM-3	21.23**	3.64**	13.51**
Varuvila-2 x TVM-1	-2.92	-11.65**	-21.57**
Varuvila-2 x KMV-1	-3.37**	-20.83**	-15.55**
Varuvila-2 x TVM-3	-3.84**	-21.17**	-12.03**
VS-86 x TVM-1	18.25**	-5.77**	1.69
VS-86 x KMV-1	26.32**	17.73**	17.99**
VS-86 x TVM-3	6.82**	-0.41	4.74**
P-1 x TVM-1	31.44**	4.74**	6.00**
P-1 x KMV-1	1.72	-16.96**	-11.31**
P-1 x TVM-3	-0.38	-18.68**	-9.11**
Malika x TVM-1	-17.35**	-34.10**	-26.68**
Malika x KMV-1	21.61**	13.86**	17.65**
Malika x TVM-3	-8.01	-8.00**	-6.46**
CD	0.53	0.53	0.46

Table 25. Heterosis(%) for root weight per plant

Characters	SH	HB	RH
Vellayani local x TVM-1	-15.66**	10.57*	21.69**
Vellayani local x KMV-1	26.18**	-15.87**	-9.97**
Vellayani local x TVM-3	-20.79**	-34.14**	-19.40**
Varuvila-2 x TVM-1	6.60**	36.67**	51.92**
Varuvila-2 x KMV-1	18.08**	34.56**	42.47**
Varuvila-2 x TVM-3	-1.47	-18.07**	-0.59
VS-86 x TVM-1	21.01**	0.61	32.53**
VS-86 x KMV-1	-35.94**	-46.42**	-38.39**
VS-86 x TVM-3	-15.66**	-29.87**	-29.87**
P-1 x TVM-1	-29.85**	-11.96**	-1.18
P-1 x KMV-1	-0.51	13.37**	18.83**
P-1 x TVM-3	-34.73**	-45.73**	-34.70**
Malika x TVM-1	-17.38**	-17.38**	1.76
Malika x KMV-1	19.91**	19.91**	27.73**
Malika x TVM-3	-13.71**	-28.26**	-21.67**
CD	1.07	1.07	0.92

Table 26. Heterosis(%) for nodules per plant

Characters	SH	HB	RH
Vellayani local x TVM-1	-33.35**	-14.93**	-9.77**
Vellayani local x KMV-1	7.21**	15.10**	25.07**
Vellayani local x TVM-3	10.98**	4.51**	20.28*
Varuvila-2 x TVM-1	-24.74**	6.33**	7.35**
Varuvila-2 x KMV-1	-9.28**	-2.60	10.69**
Varuvila-2 x TVM-3	-15.46**	-20.38**	-4.43**
VS-86 x TVM-1	-18.19**	-22.96**	-6.81**
VS-86 x KMV-1	1.39	-4.51**	1.75
VS-86 x TVM-3	10.98**	4.51**	4.57**
P-1 x TVM-1	-19.54**	-3.72	4.93**
P-1 x KMV-1	30.57**	-25.45**	-21.23**
P-1 x TVM-3	-10.31**	-15.53**	-5.23**
Malika x TVM-1	10.67**	10.67**	30.67**
Malika x KMV-1	-1.03	-1.03	2.51
Malika x TVM-3	-23.04**	-27.52**	-25.35**
CD	0.75	0.75	0.65



X1	Vellayani x TVM-1	X6	Varuvila-2 x TVM-3	X11	P-1x KMV-1
X2	Vellayani x KMV-1	X7	VS-86x TVM-1	X12	P-1x TVM-3
X3	Vellayani x TVM-3	X8	VS-86x KMV-1	X13	Malika x TVM-1
X4	Varuvila-2 x TVM-1	X9	VS-86x TVM-3	X14	Malika x KMV-1
X5	Varuvila-2 x KMV-1	X10	P-1x TVM-1	X15	Malika x TVM-3

Fig. 3. Continued

standard heterosis was shown by crosses, Vellayani local x KMV-1 (7.36); Varuvila-2 x TVM-1 (7.36); Varuvila-2 x KMV-1 (6.22); VS-86 x TVM-1 (8.69); P-1 x KMV-1 (35.49); P-1 x TVM-3 (14.92) and Malika x TVM-1 (16.41). Significant positive heterobeltiosis was shown by crosses Varuvila-2 x TVM-1 (32.37); Varuvila-2 x KMV-1 (16.81); P-1 x KMV-1 (5.30) and Malika x TVM-1 (16.41). Significant positive relative heterosis was shown by Vellayani local x TVM-1 (4.76); Vellayani local x KMV-1 (9.31); Varuvila-2 x TVM-1 (39.44), Varuvila-2 x KMV-1 (23.45); VS-86 x TVM-1 (4.17); P-1 x KMV-1 (23.35) and Malika x TVM-1 (34.72).

4.5.12 Pod breadth (cm)

The values for heterosis ranged from –32.65 (P-1 x KMV-1) to 11.22 (Malika x TVM-1) for standard heterosis, –36.28 (Vellayani local x KMV-1) to 15.31 (Malika x KMV-1) for heterobeltiosis and –31.25 (Vellayani local x TVM-3) to 11.22 (Malika x TVM-1) for relative heterosis. Significant positive standard heterosis was shown by crosses VS-86 x TVM-3 (9.18) and Malika x TVM-1 (11.22). Significant positive heterobeltiosis was shown by crosses VS-86 x TVM-3 (15.05); Malika x TVM-1 (10.10) and Malika x KMV-1 (15.31). Significant positive relative heterosis was shown by the cross, Malika x TVM-1 (11.22).

4.5.13 Seeds per pod

The value of heterosis ranged from –22.36 (Varuvila-2 x TVM-1) to 30.50 (Vellayani local x KMV-1) for standard heterosis; 44.23 (VS-86 x TVM-3) to 22.22 (Vellayani local x TVM-3) for heterobeltiosis and –27.63 (VS-86 x TVM-3) to 38.24 (Vellayani local x TVM-3) for relative heterosis. Significant positive standard heterosis was shown by crosses, Vellayani local x KMV-1 (30.50); Vellayani local x TVM-3 (28.07); Varuvila-2 x KMV-1 (15.21); Varuvila-2 x TVM-3 (10.50), VS-86 x TVM-1 (7.14) and P-1 x KMV-1 (22.36). Significant positive heterobeltiosis and relative heterosis was shown by crosses Vellayani local x KMV-1 (17.11 and 20.75); Vellayani local x

Table 27. Heterosis(%) for days to first harvest

Characters	SH	HB	RH
Vellayani local x TVM-1	0	-0.48	0.23
Vellayani local x KMV-1	1.91**	-0.79**	1.01**
Vellayani local x TVM-3	0.59**	0.10	0.82**
Varuvila-2 x TVM-1	-1.78**	-2.25**	-1.15**
Varuvila-2 x KMV-1	0	-2.65**	-0.48**
Varuvila-2 x TVM-3	-0.84**	-1.31**	-0.18
VS-86 x TVM-1	1.07**	-1.61**	-0.52**
VS-86 x KMV-1	2.5**	-0.22	-0.22
VS-86 x TVM-3	0.36	-2.31**	-1.23**
P-1 x TVM-1	3.09**	1.05	1.81**
P-1 x KMV-1	5.23**	2.43**	2.79**
P-1 x TVM-3	-0.23	-2.20**	-1.46**
Malika x TVM-1	0.59**	0.10	0.35
Malika x KMV-1	1.78**	-0.92**	0.42
Malika x TVM-3	-0.35	-0.83**	-0.58**
CD	0.28	0.28	0.25

Table 28. Heterosis(%) for crude fibre content

Characters	SH	HB	RH
Vellayani local x TVM-1	-11.00**	-3.26	0
Vellayani local x KMV-1	4.00	-4.35	6.17
Vellayani local x TVM-3	-5.50	-6.89	-2.32
Varuvila-2 x TVM-1	1.50	0	8.55
Varuvila-2 x KMV-1	-19.50	-20.69**	-15.48**
Varuvila-2 x TVM-3	3.50	1.97	-1.97
VS-86 x TVM-1	-13.00**	1.16	3.57
VS-86 x KMV-1	-13.50**	-2.80	-1.17
VS-86 x TVM-3	-14.00**	-15.27**	-6.01
P-1 x TVM-1	2.00	-13.92**	-0.24
P-1 x KMV-1	1.00	-14.76**	-2.41
P-1 x TVM-3	-3.50	-18.56**	-12.27**
Malika x TVM-1	-8.00	-8.00	-1.07
Malika x KMV-1	-12.00**	-12.00**	-6.87
Malika x TVM-3	-8.00	-9.36	-8.91
CD	0.19	0.19	0.17

Table 29. Heterosis(%) for protein content

Characters	SH	HB	RH
Vellayani local x TVM-1	-20.19**	-24.40**	-11.96**
Vellayani local x KMV-1	-11.62**	-10.71**	1.16
Vellayani local x TVM-3	-1.01	-1.93	13.00**
Varuvila-2 x TVM-1	6.06	-11.39**	-5.82
Varuvila-2 x KMV-1	6.56	-10.97**	-2.53
Varuvila-2 x TVM-3	8.07	-9.71**	-2.95
VS-86 x TVM-1	-24.24**	-28.23**	-13.29**
VS-86 x KMV-1	-6.56	-5.60	11.11**
VS-86 x TVM-3	-20.71**	-23.04**	-7.92
P-1 x TVM-1	-13.63**	-4.25	1.35
P-1 x KMV-1	12.12**	-5.53	3.02
P-1 x TVM-3	-4.04	-19.15	-13.44**
Malika x TVM-1	5.04	-0.49	2.20
Malika x KMV-1	2.53	2.53	3.06
Malika x TVM-3	2.53	-0.48	1.00
CD	5.92	5.92	5.13

Table 30. Heterosis(%) for peroxidase

Characters	SH	HB	RH
Vellayani local x TVM-1	-41.67**	-38.59**	-25.53
Vellayani local x KMV-1	-58.33**	-32.43	-12.28
Vellayani local x TVM-3	-38.33**	0	2.78
Varuvila-2 x TVM-1	12.50	46.00**	-25.82**
Varuvila-2 x KMV-1	-25.00	-64.00**	-37.93**
Varuvila-2 x TVM-3	-33.33**	-68.00**	-50.00
VS-86 x TVM-1	-50.00**	-43.85**	-46.43**
VS-86 x KMV-1	-8.33	0	46.67**
VS-86 x TVM-3	-14.17	-6.36	14.40
P-1 x TVM-1	-88.33**	87-72**	-87.5**
P-1 x KMV-1	-54.17**	-50.00**	-29.67
P-1 x TVM-3	-31.67**	-25.45	-8.90
Malika x TVM-1	-88.33**	-14.16	-11.96
Malika x KMV-1	-61.67**	-61.67**	-42.50**
Malika x TVM-3	-46.67**	-46.67	-32.63**
CD	0.03	0.03	0.03

Table 31. Heterosis(%) for polyphenol oxidase

Characters	SH	HB	RH
Vellayani local x TVM-1	-45.0	-45.0	-15.4
Vellayani local x KMV-1	0.0	-33.3	11.1
Vellayani local x TVM-3	-50.0	-33.3	-4.7
Varuvila-2 x TVM-1	-37.5	-37.5	-28.5
Varuvila-2 x KMV-1	-25.0	-50.0	-33.3
Varuvila-2 x TVM-3	-50.0	-33.3	-33.3
VS-86 x TVM-1	-72.5	-72.5	-63.3
VS-86 x KMV-1	-15.0	-43.3	-15.0
VS-86 x TVM-3	-62.5	-50.0	-40.0
P-1 x TVM-1	22.5	-2.0	8.9
P-1 x KMV-1	12.5	-25.0	-18.2
P-1 x TVM-3	-25.0	-40.0	-25.0
Malika x TVM-1	0	0	0
Malika x KMV-1	0	-33.3	-20.0
Malika x TVM-3	-25.0	-25.0	-14.3
CD	0.005	0.005	0.004

Table 32. Heterosis(%) for total phenols

Characters	SH	HB	RH
Vellayani local x TVM-1	1.64**	-2.19	-0.98
Vellayani local x KMV-1	-3.47**	-4.77**	-3.56**
Vellayani local x TVM-3	-1.37	-2.70**	-0.83
Varuvila-2 x TVM-1	1.37	-2.46	-1.51
Varuvila-2 x KMV-1	0.73	-1.25	0.27
Varuvila-2 x TVM-3	-3.19**	-5.10**	-3.02**
VS-86 x TVM-1	1.09	-2.72**	-1.95
VS-86 x KMV-1	1.37	-0.89	0.72
VS-86 x TVM-3	-2.74**	-4.91**	-2.65**
P-1 x TVM-1	1.64**	-2.19	-0.71
P-1 x KMV-1	0.73	0	-0.91
P-1 x TVM-3	-5.29**	-5.98**	-4.42**
Malika x TVM-1	1.09	-2.72**	-0.81
Malika x KMV-1	0.73	0.73	1.28
Malika x TVM-3	1.64**	1.64	2.86**
CD	0.285	0.285	0.25

TVM-3 (22.22 and 38.24); Varuvila-2 x TVM-3 (22.09 and 29.24) and P-1 x KMV-1 (9.81and 16.77) respectively.

4.5.14 100 seed weight(g)

The value of heterosis ranged from –17.35 (Malika x TVM-1) to 31.40 (P-1 x TVM-1) for standard heterosis; -34.11 (Malika x TVM-1) to 17.78 (VS-86 x KMV-1) for heterobeltiosis and –26.68 (Malika x TVM-1) to 17.99 (VS-86 x KMV-1) for relative heterosis. Significant positive standard heterosis was shown by crosses, Vellayani local x TVM-1 (29.69); Vellayani local x KMV-1 (8.07); Vellayani local x TVM-3 (21.23), VS-86 x TVM-1 (18.24); VS-86 x KMV-1 (26.32); VS-86 x TVM-3 (6.80); P-1 x TVM-1 (31.40) and Malika x KMV-1 (21.61). Significant positive heterobeltiosis was shown by crosses, Vellayani local x TVM-1 (3.39); Vellayani local x TVM-3 (3.64); VS-86 x KMV-1 (17.78); P-1 x TVM-1 (4.76) and Malika x KMV-1 (13.86). Significant positive relative heterosis was shown by crosses, Vellayani local x TVM-1 (7.03); Vellayani local x TVM-3 (13.51); VS-86 x KMV-1 (17.99); VS-86 x TVM-3 (4.74); P-1 x TVM-1 (6.00) and Malika x KMV-1 (17.65).

4.5.15 Root weight per plant(g)

The value of heterosis ranged from –35.94 (VS-86 x KMV-1) to 21.01 (VS-86 x TVM-1) for standard heterosis, -46.42 (VS-86 x KMV-1) to 36.67 (Varuvila-2 x TVM-1) for heterobeltiosis and –38.39 (VS-86 x KMV-1) to 51.92 (Varuvila-2 x TVM-1) for relative heterosis. The crosses, Varuvila-2 x TVM-1 (6.60, 36.67 and 51.92); Varuvila-2 x KMV-1 (18.08, 34.56 and 42.47) and Malika x KMV-1 (19.91, and 19.91 and 27.73) showed significant positive standard heterosis, heterobeltiosis and relative heterosis respectively.

4.5.16 Nodules per plant

The value of heterosis ranged from –33.35 (Vellayani local x TVM-1) to 10.98 (VS-86 x TVM-3 and Vellayani local x TVM-3) for standard heterosis; -27.52 (Malika x TVM-3) to 15.1 (Vellayani local x KMV-1) for heterobeltiosis

and –25.35 (Malika x TVM-3) to 30.67 (Malika x TVM-1) for relative heterosis. The crosses, Vellayani local x KMV-1 (7.21 and 15.10); Vellayani local x TVM-3 (10.98 and 4.51); VS-86 x TVM-3 (10.98 and 4.51) and Malika x TVM-1 (10.67 and 10.67) showed significant positive standard heterosis and heterobeltiosis respectively. The crosses, Vellayani local x KMV-1 (25.07); Vellayani local x TVM-3 (20.28); Varuvila-2 x TVM-1 (7.35); Varuvila-2 x KMV-1 (10.69); VS-86 x TVM-3 (4.51); P-1 x TVM-1 (4.93) and Malika x TVM-1 (30.67) showed significant positive relative heterosis.

4.5.17 Days to first harvest

The value of heterosis ranged from –1.78 (Varuvila-2 x TVM-1) to 5.23 (P-1 x KMV-1) for standard heterosis; -2.65 (Varuvila-2 x KMV-1) to 2.43 (P-1 x KMV-1) for heterobeltiosis and –1.46 (P-1 x TVM-3) to 2.79 (P-1 x KMV-1) for relative heterosis. Significant negative standard heterosis was shown by crosses Varuvila-2 x TVM-1(-1.78) and Varuvila-2 x TVM-3(-0.84). Significant negative heterobeltiosis was shown by crosses, Vellayani local x KMV-1 (-0.79),Varuvila-2 x TVM-1 (-2.25), Varuvila-2 x KMV-1 (-2.65), Varuvila-2 x TVM-3(-1.31),VS-86 x TVM-1(-1.61),VS-86 x TVM-3(-2.31), P-1 x TVM-3(-2.20) Malika x KMV-1(-0.92) and Malika x TVM-3(-0.83). The crosses, Varuvila -2 x TVM-1(-1.15), Varuvila-2 x KMV-1(-0.48),VS-86 x TVM-1(-0.52),VS-86 x TVM-3(-1.23), P-1 x TVM-3(-1.46) and Malika x TVM-3(-0.58) showed significant negative relative heterosis.

4.5.18 Crude fibre content(%)

The value of heterosis ranged from –19.50 (Varuvila-2 x KMV-1) to 4.00(Vellayani local x KMV-1) for standard heterosis, -20.69 (Varuvila-2 x KMV-1) to 1.97 (Varuvila-2 x TVM-3) for heterobeltiosis and –15.48 (Varuvila-2 x KMV-1) to 8.55 (Varuvila-2 x TVM-1) for relative heterosis. The crosses Vellayani local x TVM-1(-11.00); VS-86 x TVM-1(-13.00) ;VS-86 x KMV-1(-13.50) ; VS-86 x TVM-3(-14.00) and Malika x KMV-1(-12.00) showed significant negative standard heterosis. Seven crosses showed

significant negative heterobeltiosis.Varuvila-2 x KMV-1(-15.48) and P-1 x TVM-3(-12.27) showed significant negative relative heterosis.

4.5.19 Protein content (g)

The value of heterosis ranged from –24.24 (VS-86 x TVM-1) to 13.63 (P-1 x TVM-1) for standard heterosis; -28.23 (VS-86 x TVM-1) to 2.53 (Malika x KMV-1) for heterobeltiosis and –13.44 (P-1 x TVM-3) to 13.00 (Vellayani local x TVM-3) for relative heterosis. The crosses P-1 x TVM-1 (13.63) and P-1 x KMV-1 (12.12) showed significant positive standard heterosis and crosses, Vellayani local x TVM-3 (13.00) and VS-86 x KMV-1 (11.11) showed significant positive relative heterosis. None of the crosses showed positive and significant values for heterobeltiosis.

4.5.20 Peroxidase

The value of heterosis ranged from –88.33 (P-1 x TVM-1 and Malika x TVM-1) to 12.50 (Varuvila-2 x TVM-1) for standard heterosis; -68.00 (Varuvila-2 x TVM-3) to 87.72 (P-1 x TVM-1) for heterobeltiosis and -87.50(P-1x TVM-1) to 46.67 (VS-86 x KMV-1) for relative heterosis. None of the crosses showed significant positive standard heterosis. Significant positive heterobeltiosis was shown by crosses, Varuvila-2 x TVM-1 (46.00) and P-1 x TVM-1 (87.72). Positive and significant value for relative heterosis was shown by the cross, VS-86 x KMV-1 (46.67).

4.5.21 Polyphenol oxidase

The value of heterosis ranged from –72.5 (VS-86 x TVM-1) to 22.5 (P-1 x TVM-1) for standard heterosis; -72.5 (VS-86 x TVM-1) to –2.0 (P-1 x TVM-1) for heterobeltiosis and –63.3 (VS-86 x TVM-1) to 11.1 (Vellayani local x KMV-1) for relative heterosis. None of the crosses showed significant value for heterosis.

4.5.22 Total phenols

The value of heterosis ranged from –5.29 (P-1 x TVM-3) to 1.64 (Vellayani local x TVM-1, P-1 x TVM-1 and Malika x TVM-3) for standard heterosis; -5.98 (P-1 x TVM-3) to 1.64 (Malika x TVM-3) for heterobeltiosis

and –4.42 (P-1 x TVM-3) to 2.86 (Malika x TVM-3) for relative heterosis. None of the crosses shown significant positive values for heterobeltiosis and relative heterosis.All crosses having a value of 1.64 showed significant positive standard heterosis. None of the crosses showed significant positive heterobeltiosis. Malika x TVM-3 (2.86) showed significant positive relative heterosis.

4.6 DISEASE INTENSITY

Based on the multicelled macroconidia (sickle shaped) and single celled microconidia, the pathogen was identified as *Fusarium oxysporum* (Plate 3). Disease intensity at tenth and twentieth days after application of inoculum was found to be non-significant. The genotypes were found to be highly significant. Among crosses, VS-86 x TVM-1 showed the least percentage of mortality(29.49%), followed by Varuvila-2 x TVM-3 and P-1 x TVM-3 both having 44.46%. Highest percentage of mortality was shown by crosses, Varuvila-2 x KMV-1 and Malika x TVM-3 (99.98%) followed by Vellayani local x KMV-1, Vellayani local x TVM-3, P-1 x KMV-1, Malika x KMV-1 and Malika x TVM-1 (94.48%). Among the lines, P-1 showed least mortality (59.96%) whereas highest mortality was shown by VS-86 (99.98 %). Among testers least mortality was shown by TVM-1 (60.97 %), followed by TVM-3 (70.48 %) and KMV-1 (75.4 %).Disease intensity of various treatments are represented in the Table 33,Plate 8.

Thus on the basis of mean performance, combining ability and standard heterosis, P-1 x TVM-1 was found to be superior for main stem length, 100 seed weight and polyphenol oxidase activity. VS-86 x TVM-1 was found to be superior for pod yield per plant. Vellayani local x TVM-3, P-1x KMV-1, Malika x TVM-1 and Vellayani local x TVM-1 showed superiority for characters like nodules per plant, pod length, pod weight and pods per plant respectively. The crosses, VS-86 x TVM-1 was found to be most promising for yield and Fusarium wilt resistance. The crosses, Varuvila-2 x TVM-1 and P-1 x TVM-3 were also found superior for yield and resistance to Fusarium wilt. Promising hybrids based on mean performance, sca effects and standard heterosis is given in Table 34.

Table 33. Disease intensity of parents and hybrids

Treatment	Per cent death after first application of inoculation	Per cent death after second application of inoculation	Average
Vellayani local	88.38 (70.075)	88.38 (70.075)	88.38 (70.075)
Varuvila-2	94.48 (76.42)	94.48 (76.42)	94.48 (76.42)
VS-86	99.98 (89.40)	99.98 (89.40)	99.98 (89.40)
P-1	59.96 (50.75)	59.96 (50.75)	59.96 (50.75)
Malika	94.48 (73.42)	99.98 (89.40)	98.47 (82.91)
TVM-1	94.48 (76.42)	94.48 (76.42)	60.97 (51.33)
KMV-1	70.48 (57.095)	80.007 (63.44)	75.40 (60.27)
TVM-3	70.48 (57.095)	70.48 (57.095)	70.48 (57.09)
Vellayani local x TVM-1	88.38 (70.095)	88.38 (70.095)	88.38 (70.095)
Vellayani local x KMV-1	94.48 (76.42)	94.48 (76.42)	94.48 (76.42)
Vellayani local x TVM-3	94.48 (76.42)	94.48 (76.42)	94.48 (76.42)
Varuvila-2 x TVM-1	70.48 (57.095)	80.007 (63.44)	75.40 (60.27)
Varuvila-2 x KMV-1	99.98 (89.4)	99.98 (89.40)	99.98 (89.40)
Varuvila-2 x TVM-3	49.98 (44.99)	39.02 (38.655)	44.46 (41.82)
VS-86 x TVM-1	29.49 (32.895)	29.49 (32.895)	29.49 (32.89)
VS-86 x KMV-1	60.97 (51.335)	60.97 (51.335)	60.97 (51.335)
VS-86 x TVM-3	60.97 (51.335)	60.97 (51.335)	60.97 (51.335)
P-1 x TVM-1	80.007 (63.44)	94.48 (76.42)	88.22 (69.93)
P-1 x KMV-1	94.48 (76.42)	94.48 (76.42)	94.48 (76.42)
P-1 x TVM-3	49.82 (44.99)	39.02 (38.655)	44.46 (41.82)
Malika x TVM-1	94.48 (76.42)	94.48 (76.42)	94.48 (76.42)
Malika x KMV-1	94.48 (76.42)	94.48 (76.42)	94.48 (76.42)
Malika x TVM-3	99.98 (89.4)	94.48 (76.42)	99.98 (89.40)
	84.17 (66.55)	85.58 (67.68)	CD = 30.89

* Transformed values are given in parenthesis

0 1

2 3

4 5

Plate 8. Varying levels of germination noticed after inoculation with *F. oxysporum*

Table 34. Promising hybrids based on mean performance, sca effects and standard heterosis and Fusarium wilt disease resistance

Crosses	Characters
VS-86 x TVM-1	Pod yield per plant, Fusarium wilt resistance
Vellayani local x TVM-3	Nodules per plant
Vellayani local x TVM-1	Pods per plant
P-1 x TVM-1	Main stem length, 100 seed weight, Polyphenol oxidase, Pod yield per plant, Fusarium wilt
P-1 x KMV-1	Pod length
Malika x TVM-1	Pod weight

Discussion

5. DISCUSSION

Field experiments as well as pot culture studies were carried out in yard long bean for combining ability, gene action, heterosis and Fusarium wilt disease intensity. The aim was to study the combining ability variances and the nature of gene action involved in important quantitative and biochemical characters and Fusarium wilt resistance in Line x Tester progenies of yard long bean. The field study was conducted in two experiments *viz.*, Experiment-I - crossing block. Experiment-II (a)- field evaluation of F_1s and parents, II (b) - pot culture studies for screening for Fusarium wilt disease resistance among lines, testers and their progenies. The experimental results are discussed here.

5.1 MEAN PERFORMANCE

Five yard long bean genotypes having high yield and moderate Fusarium wilt resistance and three genotypes having high Fusarium wilt resistance were selected as lines and tester respectively from the previous PG project entitled "Genetic variability for yield and Fusarium wilt resistance in yard long bean [*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt]".

Among lines, VS-86 was found superior based on mean performance for pod yield per plant, pod weight, pod length, seeds per pod, root weight per plant, total phenols, nodules per plant, days to 50 per cent flowering and crude fibre content. P-1 recorded maximum value for primary branches per plant, main stem length, pod per clusters 100 seed weight and polyphenol oxidase activity. Malika recorded maximum number of pods per cluster same as that of P-1 .Varuvila-2 was found superior for days to 50 per cent flowering, pod clusters per plant, pods per plant and days to first harvest, protein content and peroxidase activity. Vellayani local recorded minimum length of harvest period, crop duration and maximum pod breadth.

Among testers, TVM-1 was found superior in majority of the characters like, days to 50 per cent flowering, primary branches per plant,

pod clusters per plant, pods per plant, pod yield per plant, pod per clusters, pod weight, pod breadth, 100 seed weight and days to first harvest, crude fibre content, protein content, peroxidase, total phenols. The tester, KMV-1 showed superiority over other testers for traits like seeds per pod, length of harvest period, crop duration and polyphenol oxidase. TVM-3 showed maximum mean value for main stem length, pod yield, root weight per plant, nodules per plant and minimum value for days to first harvest.

Among crosses, VS-86 x TVM-1 was found superior based on mean performance for days to 50 per cent flowering, pod yield per plant and root weight per plant. Maximum mean performance for pod weight and pod breadth was recorded for the cross, Malika x TVM-1. The cross, VS-86 x KVM-1 had lowest value for length of harvest period and crop duration. Vellayani local x TVM-1 showed highest mean values for pod clusters per plant, total phenols and pods per plant. Highest mean values for main stem length and 100 seed weight was recorded for the cross, P-1 x TVM-1.

5.2 COMBINING ABILITY ANALYSIS

Information on nature of general combining ability and specific combining ability with respect to parents and hybrids will facilitate the breeder to plan the breeding programme effectively.

From the combining ability analysis, it is found that the line P-1 is an outstanding general combiner for six characters *viz.*, main stem length, pod yield per plant, pod weight, pod length, protein content and polyphenol oxidase. The line, Varuvila-2 had significant gca effects for root weight per plant, nodules per plant, perodixase and days to first harvest. Like wise, Vellayani local showed significant gca effects for pod clusters per plant, pods per plant, seeds per pod and 100 seed weight. Significant gca effects for the characters, days to 50 per cent flowering, length of harvest period, crop duration and primary branches per plant was shown by line VS-86. The line, Malika showed significant gca effects for pod breadth, crude fibre content and total phenol content.

Among the three testers, TVM-1 was found to be an outstanding general combiner for nine characters, days to 50 per cent flowering, primary branches per plant, pod clusters per plant, pods per plant, pod yield per plant, pod weight, pod breadth, 100 seed weight and total phenol content. KMV-1, had significant gca effects for length of harvest period, crop duration, pod length, seeds per pod, root weight per plant, crude fibre content, protein content and polyphenol oxidase. The third tester, TVM-3 showed significant gca effects for main stem length, pods per cluster, nodules per plant, days to first harvest.

Among the 15 crosses evaluated, P-1 x TVM-3 showed significant sca effect for days to 50 per cent flowering, crop duration, pod yield per plant and days to first harvest. VS-86 x TVM-1 showed significant sca effect for pod length, seeds per pod and root weight per plant. Likewise, Malika x TVM-1 showed significant sca effect for pod weight, nodules per plant and poly phenol oxidase. Combining ability effects for each character are discussed here.

5.2.1. Days to 50 per cent flowering

Variation among lines and testers were not significant. Hence an estimate of additive genetic variance had no relevance. sca variance was found to be significant. Dominant gene action was responsible for this. Similar findings were reported by Pandey and Upadhyay (1999) and Anbumalarmathi *et al.* (2004) in other crops. Importance of both gca and sca effects were earlier reported by Mishra *et al.* (1987). Rejatha (1992) reported contrary results in cowpea. Among lines, VS-86 and among testers, TVM-1 showed significant negative gca effects and were good general combiners. The crosses, P-1 x TVM-3 and Varuvila-2 x KMV-1 were good specific combiners as they exhibited significant negative sca effects. Similarly various other good general combiners for days to 50 per cent flowering was earlier reported by Pal *et al.* (2002)in cowpea.

5.2.2 Length of harvest period (days)

Significant variation among crosses were observed. Specific combining ability variance was significant and of higher magnitude indicating the predominance of dominant gene action in the expression of this character. Line, VS-86 was found to have significant negative gca effect for length of harvest period. Among testers, KMV-1 showed negative gca effect. Out of the 15 crosses, six crosses showed significant negative sca effects. Vellayani local x TVM-1 and Malika x TVM-3 showed maximum negative sca effects and were considered good specific combiners.

5.2.3 Crop duration (days)

The involvement of dominant gene action for crop duration was indicated by the predominance of sca variance over gca variance. Significant negative gca effect was shown by the line VS-86. Among testers, KMV-1 and TVM-3 showed negative gca effect. The crosses, P-1 x TVM-3; Varuvila-2 x KMV-1, Varuvila-2 x TVM-1 and Malika x TVM-3 showed significant negative sca effects.

5.2.4 Primary branches per plant

For Primary branches per plant, sca effect was found to be significant. So this character is under the control of dominant gene action. Similar results were reported by Pandey and Upadhyay (1999), Kumar *et al.*(2001) and Manivannan *et al.*(2002)in other crops.Importance of both additive and non additive effects were reported by Jeena and Arora (2001). Contrary results were reported by Jayarani *et al.* (1993) in cowpea and Anbumalarmathi *et al.* (2004) in green gram. Among lines, VS-86 was found to have significant positive gca effect for primary branches per plant. Among testers, none showed significant positive sca effect for primary branches per plant and hence considered as good specific combiners. Similar findings were reported by Singh and Mishra (2002).

5.2.5. Main stem length

Significant variation among crosses were observed. Specific combining ability variance was significant and of higher magnitude indicating the predominance of dominant gene action in the expression of this character. The lines, P-1, Vellayani local and Malika exhibited significant positive gca effect and were good general combiner. The testers, TVM-1 and TVM-3 showed significant gca effects. Among the crosses, VS-86 x TVM-3, P-1 x TVM-1, Malika x TVM-1, Vellayani local x TVM-1 and Varuvila-2 x TVM-3 showed significant positive sca effects.

5.2.6. Pod Clusters per plant

Variation among lines as well as testers were not significant. Hence an estimate of additive genetic variance had no relevance. sca variance was found to be significant. Dominant gene action was responsible for this. Similar findings were reported by Pandey and Upadhyay (1999), Singh and Dikshit(2003) and Anbumalarmathi *et al.* (2004) in other crops. Importance of both gca and sca effects were reported by Khandalkar (2004) in pigeonpea. Among lines, Vellayani local, Varuvila-2 and VS-86 and among testers, none showed positively significant gca effect for pod clusters per plant. Among 15 crosses, four exhibited positively significant sca effects. They include Vellayani local x TVM-1, Vellayani local x TVM-3; VS-86 x KMV-1 and P-1 x TVM-1. Maximum positive significant sca effect was shown by VS-86 x KMV-1.

5.2.7. Pods per plant

For pods per plant, sca effect was found to be significant. So this character was under the control of dominant gene action. Similar results were reported by Kumar(1993), Smitha (1995), Chaudhari *et al.*(1998)in cowpea, Ramalingam and Francies(1999), Sarode *et al.*(2000), Kumar *et al.* (2001), Singh and Dikshit (2003) and Anbumalarmathi *et al.* (2004)in other crops. Importance of both additive and non additive effects were reported by Jeena

and Arora (2001) and Khandalkar (2005).Contrary results were reported by Jayarani (1993) in cowpea. The lines Vellayani local, Varuvila-2 and VS-86 showed significant positive gca effect for pods per plant. None of the testers showed significant gca effect. Six crosses exhibited positively significant sca effect. The cross Varuvila-2 x KMV-1 is a good hybrid with parents having positive x negative gca effects. Good general combiners were earlier reported by Chaudhari *et al.* (1998) and best crosses were reported by Savithramma and Latha (1998) in cowpea.

5.2.8. Pods yield per plant

Significant variation among crosses were observed. Specific combining ability variance was significant and with high magnitude indicating the predominance of dominant gene action in the expression of this character. Similar results were reported by Kumar *et al.* (1998), Ramalingam and Francies (1999), Jeena and Arora (2001), Kumar *et al.*(2001) in other crops. Importance of both additive and non additive effects were reported earlier by Madhusudha *et al.* (1995) in cowpea. Contrary results were reported by Philip(2004) and Rizwana *et al.* (2006). VS-86 and P-1 are the lines that showed significant positive gca effect. Among the testers, TVM-1 showed significant positive gca effect for pod yield per plant. Four crosses, Vellayani local x KMV-1, VS-86 x TVM-1, P-1 x TVM-3 and Malika x KMV-1 showed positively significant sca effect. These crosses had their parents with negative x negative, positive x positive, positive x negative and negative x negative gca effects. Good general combiners for pod yield per plant were identified and reported earlier by Madhusuda *et al.* (1995) and Kumar *et al.* (1998) and Sawarkar *et al.* (1999) in vegetable cowpea.

5.2.9. Pods per cluster

Variation among lines as well as testers were not significant. Hence an estimate of additive genetic variance has no relevance. sca variance was found to be significant. Dominant gene action was responsible in this case. Similar results were earlier reported by Chaudhari *et al.*(1998) and Dijee *et al.*(2000) in cowpea.

None of the line showed significant positive gca effect for pods per clusters. Among testers, TVM-3 showed significant positive gca effect. The crosses, Vellayani local x TVM-1, Vellayani local x KMV-1; Varuvila-2 x KMV-1; VS-86 x TVM-3; P-1 x TVM-1 showed significant positive sca effect and were found to be good specific combiners.

5.2.10. Pod weight (g)

For Pod weight, sca effect was found to be significant. So this character was under the control of dominant gene action. Contrary result was reported by Rejatha (1992).The lines, Vellayani local, P-1 and Malika exhibited significant positive gca effects. Significant gca effect for pod weight was shown by TVM-1. Four crosses, Vellayani local x TVM-3, VS-86 x TVM-1, P-1 x TVM-3 and Malika x TVM-1 which had their parents with positive x negative, negative x positive, positive x negative and positive x positive gca effects respectively showed significant positive sca effects.

5.2.11. Pod length (cm)

Significant variation among crosses were observed. Specific combining ability variance was significant and of higher magnitude indicating the predominance of dominant gene action in the expression of this character. Similar results were reported by Singh and Dikshit(2003). Contrary results were reported by Philip(2004) in cowpea. The line, P-1 showed positively significant gca effect and testers, TVM-1 and KMV-1 showed positively significant gca effect for pod length. Five crosses, Vellayani local x TVM-3, VS-86 x TVM-1, P-1 x KMV-1, P-1 x TVM-3 and Malika x TVM-1 showed significant positive sca effect and hence found to be good specific combiners.

5.2.12. Pod breadth (cm)

Variation among lines as well as testers were not significant. Hence an estimate of additive genetic variance had no relevance. sca variance was found to be significant. Dominant gene action was responsible for this. None of the line except Malika and all testers exhibited positively significant gca

effects for pod breadth. Among the crosses, Vellayani local x TVM-3, Varuvila-2 x KMV-1, VS-86 x TVM-3, P-1 x TVM-1, which had their parents with negative x positive, negative x negative, negative x positive, negative x positive gca effects respectively showed significant positive sca effects.

5.2.13. Seeds per pod

For seeds per pod, sca effect was found to be significant. So this character was under the control of dominant gene action. Similar results were reported by Smitha (1995) and Anbumalarmathi *et al.* (2004). Importance of both additive and non additive effects were reported earlier by Jeena and Arora (2001) in chickpea. Contrary results were reported by Thiyagaragan(1990), Jayarani (1993) and Philip(2004) in cowpea. The line, Vellayani local showed significant gca effect. Among testers, KMV-1 and TVM-3 showed significant gca effects. Seven crosses exhibited significant positive sca effect for seeds per pod. VS-86 x TVM-1 which had parents with negative x negative gca effects showed highest sca effect.

5.2.14. 100 Seed weight (g)

Significant variation among crosses were observed. Specific combining ability variance was significant and of higher magnitude indicating the predominance of dominant gene action in the expression of this character. Similar results was reported by Smitha (1995) and Anbumalarmathi *et al.* (2004). Contrary result was reported by Jayarani (1993). Positive gca effects was reported by Singh and Mishra (2002) in pea and Singh (2005) in urd bean. The lines, Vellayani local, VS-86 and P-1 exhibited significant positive gca effect whereas none of the testers exhibited significant positive gca effect for 100 seed weight. Six crosses exhibited significant positive sca effect. Among them, Malika x KMV-1 showed maximum positive sca effect which had parents with negative x positive gca effects.

5.2.15. Root weight per plant (g)

Variation among lines as well as testers were not significant. Hence an estimate of additive genetic variance had no relevance. sca variance was found to be significant. Dominant gene action was responsible in this case. Importance of non additive gene action was reported by Varghese (1997), Chaudhary *et al.*(1998) and Dijee *et al.*(2000) in cowpea. The lines, Varuvila-2 and Malika and the testers TVM-1 and KMV-1 showed significant positive gca effects for root weight per plant. The crosses, Vellayani local x TVM-3, Varuvila-2 x KMV-1, VS-86 x TVM-1, P-1 x KMV-1 and Malika x KMV-1 exhibited significant positive sca effects.

5.2.16. Nodules per plant

For seeds per pod, sca effect was found to be significant. So this character was under the control of dominant gene action. The lines, Vellayani local, VS-86 and Malika showed significant positive gca effect. Among testers, KMV-1 and TVM-3 exhibited significant positive gca effect. Seven crosses out of fifteen showed significant positive sca effects. Among them, maximum positive significant sca was shown by the cross, Malika x TVM-1.

5.2.17. Days to first harvest

Significant variation among crosses were observed. Specific combining ability variance was significant and of higher magnitude indicating the predominance of dominant gene action in the expression of this character. Similar results was reported by Pandey (2004) in pigeonpea. Contrary results reported by Jayarani (1993). Importance of both additive and dominant gene action was reported by Jeena and Arora (2001 in chickpea). The lines, Vellayani local, Varuvila-2 and Malika showed significant negative gca whereas among testers, TVM-1 and TVM-3 showed significant negative gca effects and found to be good general combiners. Four crosses, Vellayani local x TVM-1, Varuvila-2 x TVM-1, Varuvila-2 x KMV-1 and P-1 x TVM-3 showed significant negative sca effects for days to first harvest.

5.2.18. Crude fibre content (%)

The line, Malika showed maximum negatively significant gca followed by VS-86. Among testers, KMV-1 showed significant gca effects. Among the crosses, Varuvila-2 x KMV-1 with its parents having positive x negative gca effects shown the maximum negatively sca effect.

19. Protein content (g)

Among lines, P-1 and Malika exhibited significant positive gca effect. The testers KMV-1 showed positive gca effect but not significant. Three crosses out of fifteen, Vellayani local x TVM-3, VS-86 x KMV-1 and P-1 x TVM-1 showed significant positive sca effect with parents having negative x negative, negative x positive and positive x negative gca effects respectively.

20. Peroxidase

Varuvila and VS-86 are the lines that showed significant gca effect for peroxidase activity. None of the testes showed significant positive gca effect. The crosses, Varuvila x TVM-1, P-1 x TVM-3 and Malika x TVM-1 showed equal and positively significant sca effect.

21. Polyphenol oxidase

The lines P-1 and Malika and the tester, KMV-1 showed significant positive gca effect. Among the crosses, Vellayani local x KMV-1, VS-86 x KMV-1, P-1 x TVM-1 showed equal sca effect and cross Malika x TVM-1 showed maximum significant positive sca effect.

22. Total phenols

The line, Malika and the tester, TVM-1 showed significant positive gca effect. Among fifteen crosses, Vellayani local x TVM-3 and Malika x TVM-3 having parents with negative x negative and positive x negative gca effects exhibited maximum significant positive sca effects.

5.3 HETEROSIS

Existence of significant amount of dominance variance is essential for undertaking heterosis breeding programme. Even, the expression of small magnitudes of heterosis for a particular character is also very much desirable in breeding. High estimate of heterosis is a result of high genetic diversity among parents indicating the possibility of identifying high yielding transgressive segregate from hybrid population (Singh, 2002).

All the characters were subjected to line x tester analysis to study the Standard heterosis, Heterobeltiosis and Relative heterosis.

1. Days to 50 per cent flowering

Out of the 15 crosses, six showed significant negative standard heterosis, the maximum negative value shown by VS-86 x TVM-1 followed by Varuvila-2 x TVM-1. Four among the fifteen crosses showed significant negative heterobeltiosis. Three crosses showed significant positive relative heterosis, others were found to be non-significant. Bhushana *et al.* (2000) also reported negative heterosis for days to 50 per cent flowering in cowpea.

2. Length of harvest period (days)

All crosses except Malika x TVM-1 showed significant negative standard heterosis, the maximum value shown by VS-86 x KMV-1. Nine crosses exhibited significant negative heterosis. Six crosses showed significant negative relative heterosis whereas four showed significant positive relative heterosis.

3. Crop duration (days)

Thirteen crosses exhibited significant negative standard heterosis, maximum value exhibited by Varuvila-2 x TVM-3. Six crosses showed significant negative heterobeltiosis. Significant negative relative heterosis was exhibited by four crosses, whereas seven crosses exhibited significant positive relative heterosis.

4. Primary branches per plant

None of the crosses exhibited significant heterosis value for relative heterosis, heterobeltiosis and standard heterosis. Six crosses shown positive standard heterosis and five crosses each showed positive heterobeltiosis and relative heterosis. Heterosis for primary branches per plant was reported by Ningappa (1981), Rao and Chopra (1989), Bhushana *et al.* (2000), Danam and Chaudhari (2000) and Haibatpure *et al.* (2003).

5. Main stem length (cm)

Six crosses exhibited significant positive standard heterosis, maximum value shown by the cross P-1 x TVM-1. The crosses, Vellayani local x TVM-1 and Malika x TVM-1 showed significant positive heterobeltiosis. Seven crosses exhibited significant positive relative heterosis. Seven crosses exhibited significant positive relative heterosis. Malika x TVM-1 showed maximum significant positive relative heterosis. Similar findings were reported by Rao and Chopra (1989), Sawant *et al.* (1994), Bhor *et al.* (1997), Danan and Chaudhari (2000), Tyagi and Srivastava(2001) and Singh and Dikshit (2003).

6. Pod clusters per plant

All crosses except Vellayani local x TVM-1 and Vellayani local x TVM-3 showed significant negative standard heterosis. All crosses except Vellayani local x TVM-3 showed significant negative heterobeltiosis. The crosses, Vellayani local x TVM-3 and Malika x TVM-1 showed significant positive relative heterosis. The cross P-1 x TVM-3 exhibited the highest significant negative heterosis for standard, heterobeltiosis and relative heterosis. Heterosis in pods per clusters per plant was reported by Patil and Shete (1987), Danam and Chaudhary (2000) and Singh and Dikshit (2003).

7. Pods per plant

Nine crosses exhibited significant positive standard heterosis. Four crosses showed significant positive heterosis whereas seven exhibited

significant positive relative heterosis. The cross, Vellayani local x TVM-1 showed maximum standard, heterobeltiosis and relative heterosis. Similar findings were earlier reported by Bhushana *et al.* (1980), Ningappa (1981), Rao and Chopra (1989), Rejatha (1992), Sawant *et al.* (1994), Hooda *et al.* (1999), Danam and Chaudhari (2000), Haibatpure *et al.* (2003) and Singh and Dikshit (2003).

8. Pod yield per plant

The crosses, VS-86 x TVM-1 and P-1 x TVM showed significant positive standard heterosis whereas P-1 x TVM-3 showed significant positive heterobeltiosis. Significant positive relative heterosis was exhibited by crosses, P-1 x TVM-1 and P-1 x TVM-3. Similar results were reported by Bhaskaraiah *et al.* (1980), Chikkadevaiah *et al.* (1980), Ningappa (1981), Rao and Chopra (1989), Rejatha (1992), Sawant *et al.* (1994), Mathur and Mathur (2001) and Shashibushan and Chaudari (2000).

9. Pods per clusters

None of the crosses exhibited significant positive standard heterosis. The crosses, Varuvila x KMV-1 and VS-86 x TVM-3 exhibited significant positive heterobeltiosis and relative heterosis. Heterosis for pods per cluster was reported by Zaveri *et al.* (1983).

10. Pod weight (g)

Significant positive standard heterosis was shown by 11 crosses, of which maximum value was recorded by Malika x TVM-1. Two crosses showed significant positive heterobeltiosis and four crosses exhibited relative heterosis respectively. The cross, P-1 x TVM-3 recorded maximum heterobeltiosis and relative heterosis.

11. Pod length (cm)

Seven crosses each showed significant positive standard and relative heterosis for pod length. Four crosses exhibited significant positive heterobeltiosis. The cross, Varuvila-2 x TVM-1 exhibited maximum heterobeltiosis and relative

heterosis. The cross VS-86 x TVM-3 exhibited maximum negative standard heterobeltiosis and relative heterosis. Similar findings were earlier reported by Chikkadevaiah *et al.* (1980), Bhushana *et al.* (2000) and Singh and Dikshit (2003).

12. Pod breadth (cm)

Significant positive standard heterosis was exhibited by P-1 x KMV-1 and Malika x TVM-1. These two crosses Malika x KMV-1 showed significant positive heterobeltiosis. Significant positive relative heterosis was shown by Malika x TVM-1.

13. Seeds per pod

Six crosses exhibited significant positive standard heterosis for seeds per pod. Four crosses exhibited significant positive heterobeltiosis and five crosses shown significant positive relative heterosis. Maximum value for standard heterosis was exhibited by Vellayani local x KMV-1. For heterobeltiosis and relative heterosis it was Vellayani local x TVM-3. This was in accordance with the findings of Joseph and Kumar (2000), Danam and Chaudhari (2000) and Haibatpure *et al.* (2003).

14. 100 Seed weight (g)

Eight crosses exhibited significant positive standard heterosis whereas five exhibited significant positive heterobeltiosis. Six among fifteen crosses showed significant relative heterosis. Maximum heterobeltiosis and relative heterosis was exhibited by cross, VS-86 x KMV-1. Heterosis for 100 seed weight was earlier reported by Bhushana (2000), Bhaskaraiah *et al.* (1980), Chekkadevaiah *et al.* (1980), Sarode *et al.* (2000) and Singh and Dikshit (2003).

15. Root weight per plant (g)

Four crosses exhibited significant positive standard heterosis. Five showed significant positive heterobeltiosis and six crosses showed significant positive relative heterosis. Maximum heterobeltiosis and relative heterosis

was exhibited by the cross, Varuvila-2 x TVM-1. The cross, VS-86 x KMV-1 showed least standard, heterobeltiosis and relative heterosis.

16. Nodules per plant

Four crosses exhibited significant positive standard heterosis with maximum for the cross, VS-86 x TVM-3. Vellayani local x KMV-1 showed maximum heterobeltiosis. Seven crosses exhibited significant positive relative heterosis. Among this Malika x TVM-1 showed the maximum.

17. Days to first harvest

Two crosses, Varuvila-2 x TVM-1 and Varuvila-2 x TVM-3 exhibited significant negative standard heterosis. Nine crosses exhibited significant negative heterobeltiois and six shown significant negative relative heterosis. Several findings in accordance with this result has been reported by Chikkadevaiah *et al.* (1980) and Bhor *et al.* (1997) in cowpea.

Biochemical traits

Maximum significant negative standard heterosis for crude fibre content was exhibited by VS-86 x TVM-3 and Varuvila-2 x KMV-1 showed maximum significant negative heterobeltiosis and relative heterosis. The crosses that exhibited significant positive standard heterosis for protein content were P-1 x TVM-1 and P-1 x KMV-1. The crosses, Vellayani local x TVM-3 and VS-86 x KMV-1 exhibited significant positive relative heterosis for protein content. Significant positive heterobeltiosis was shown by Varuvila-2 x TVM-1 and P-1 x TVM-1 and VS-86 x KMV-1 showed significant positive heterobeltiosis was shown by Varuvila-2 x TVM-1 and P-1 x TVM-1 and VS-86 x KMV-1 showed significant positive relative heterosis for peroxidase activity. Vellayani local x TVM-1 showed significant positive standard heterosis for total phenols. None of the crosses exhibited significant positive heterobeltiosis for protein content and total phenols. Likewise none of the crosses exhibited significant positive standard heterosis and relative heterosis for peroxidase and total phenols.

5.4 DISEASE INTENSITY

Incidence of pests and diseases is a major bottleneck in the cultivation of legumes. Crop losses due to wilt disease especially those caused by *Fusarium oxysporum* continue to be a limiting factor in maximising yield in vegetables especially in cowpea. Hence this work was intended to identify the sources of resistance against Fusarium wilt and also for developing high yielding varieties of yard long bean.

Pot culture experiments done for screening yard long bean genotypes which are resistant to Fusarium wilt disease by artificial inoculation of pathogen revealed that the accessions were highly significant. But the disease intensity at two time of application of inoculum was found to be non significant. Least mortality was shown by the line P-1, the tester TVM-1 and cross VS-86 x TVM-1. Highest mortality was shown by the line VS-86, the tester KMV-1 and crosses Varuvila-2 x KMV-1 and Malika x TVM-3. Similar work were earlier done and reported by Sajise (1988), Shihata *et al.* (1989b), Pandey and Upadhyay (1999), Sala *et al.* (2001), Ravi *et al.* (2003), Madhukeshwara *et al.* (2004) .

Summary

6. SUMMARY

The present investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani local during the period 2004-2006. The work is a continuation of PG project entitled "Genetic variability for yield and Fusarium wilt resistance in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)". The aim was to study the combining ability variances and the nature of gene action involved in important quantitative and biochemical characters and Fusarium wilt resistance in Line x Tester progenies of yard long bean. The field study was conducted in two experiments *viz*., Experiment – 1 for crossing between lines and testers and Experiment-II (a) - for field evaluation of F_1s and parents, II (b) - pot culture studies for screening for Fusarium wilt disease resistance among lines, testers and their progenies.

Based on the previous experiment, five lines having high yield and moderate fusarium wilt resistance and three testers having high Fusarium wilt resistance were selected as parents and crossed in L x T pattern. Seeds of F_1s and parents were laid out in Randomised Block Design with three replications. The 15 hybrids along with their parents were evaluated for mean performance, combining ability, gene action and heterosis based on 22 characters namely, Days to 50% flowering, Days to first harvest, Length of harvest period, Crop duration, Primary branches per plant, Main stem length, Pod clusters per plant, Pods per plant, Pods yield per plant, Pods per cluster, Pod weight, Pod length, Pod breadth, Seeds per pod, 100 seed weight, Fresh weight of roots per plant, Nodules per plant, Crude fibre content, Protein content, Peroxidase, Polyphenol oxidase and Total Phenols.

Studies on combining ability showed higher magnitude of sca variance for all characters indicating the predominance of dominance gene action. Based on the mean performance, the line VS-86 was found to be superior for most of the

yield and biochemical characters and the tester TVM-1 showed superior performance for pod yield per plant and maximum yield related characters.

Based on general combining ability, the line P-1 exhibited maximum gca effect for pod yield per plant and related characters like main stem length, pod weight, pod length, protein content and polyphenol oxidase activity. Among testers, TVM-1 showed maximum gca effects for yield and related characters. Based on specific combining ability, the crosses Vellayani local x TVM-3, Varuvila-2 x KMV-1, VS-86 x KMV-1 and P-1 x TVM-1 showed maximum sca for yield and biochemical characters.

On the basis of mean performance and combining ability, the line VS-86 was superior for days to 50% flowering, P-1 was superior for main stem length and polyphenol oxidase activity, Varuvila-2 was superior for nodules per plant and peroxidase activity. Among the testers, TVM-1 was found superior for the characters, days to 50% flowering, primary branches per plant, pod clusters per plant, pods per plant, pod yield per plant, pod weight, pod breadth, 100 seed weight and total phenols. KMV-1 was superior for length of harvest period, crop duration, seeds per pod and polyphenol oxidase activity.TVM-3 was superior for main stem length, nodules per plant and days to first harvest based on mean performance and combining ability. Among the crosses, P-1 x TVM-1 showed superiority for the characters, main stem length, 100 seed weight and polyphenol oxidase activity. Varuvila-2 x TVM-1 showed superior performance for days to first harvest and peroxidase activity. Among crosses VS-86 x TVM-1 was found to be superior for pod yield per plant and root weight per plant.

On the basis of mean performance, combining ability and standard heterosis, P-1 x TVM-1 was found to be superior for main stem length, 100 seed weight and polyphenol oxidase activity. VS-86 x TVM-1 was found to be superior for pod yield per plant. Vellayani local x TVM-3, P-1x KMV-1, Malika x TVM-1 and Vellayani local x TVM-1 showed superiority for characters like nodules per plant, pod length, pod weight and pods per plant respectively.

The relative contribution of crosses to the total variance were maximum for majority of the characters where as testers had the least contribution to the total variance with respect to crosses and lines.

Pot culture experiments were done for screening cowpea genotypes resistant to Fusarium wilt disease by artificial inoculation of pathogen. The study revealed that the treatments were highly significant where as disease intensity at tenth and twentieth days after application of inoculum was found to be non significant. Least mortality was shown by the line P-1, the tester TVM-1 and cross VS-86 x TVM-1. Highest mortality was shown by the line VS-86, the tester KMV-1 and crosses Varuvila-2 x KMV-1 and Malika x TVM-3.

Critical assessment of results suggest that the crosses VS-86 x TVM-1 was found to be most superior for yield, biochemical characters and fusarium wilt disease resistance. The crosses P-1 x TVM-1 and Vellayani local x TVM-1 were also found superior for these characters. Thus the work can be continued with these crosses for evolving varieties superior for yield and fusarium wilt disease resistance.

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*Original not seen

GENETIC ANALYSIS OF YIELD AND FUSARIUM WILT RESISTANCE IN LINE × TESTER PROGENY OF YARD LONG BEAN

(*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)

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Abstract of the
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ABSTRACT

A research programme was carried at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2004-2006 with the object of studying the combining ability variances and the nature of gene action involved in important quantitative and biochemical characters and Fusarium wilt resistance in line x tester progenies of yard long bean.

Based on the previous PG project entitled "Genetic variability for yield and Fusarium wilt resistance in yard long bean (*Vigna unguiculata* subsp. *sesquipealis (L.)Verdcourt)*", five lines having high yield and moderate fusarium wilt resistance and three testers having high fusarium wilt resistance was selected as parents. They were crossed in Lx T pattern and seeds of F_1s and parents were laid out in Randomised Block Design with three replications. The fifteen crosses along with their parents were evaluated for mean performance, combining ability, gene action and heterosis based on 22 characters namely, days to 50% flowering, days to first harvest, length of harvest period, crop duration, primary branches per plant, main stem length, pod clusters per plant, pods per plant, pods yield per plant, pods per cluster, pod weight, pod length, pod breadth, seeds per pod, 100 seed weight, fresh weight of roots per plant, nodules per plant, crude fibre content, protein content, peroxidase, polyphenol oxidase and total phenols.

Significant differences among treatments were observed for all characters especially pod yield per plant. The magnitude of sca variance alone was significant suggesting the importance of the dominance gene action in controlling the quantitative and biochemical characters of yard long bean.

Based on the mean performance and gca effects,VS-86 was found to be good general combiner among lines and TVM-1 among testers. The cross, P-1x TVM-1 was found to be promising for main stem length,100 seed weight and polyphenol oxidase and VS-86 x TVM-1 was superior for

pod yield per plant based on mean performance, sca effects and standard heterosis. Hence these crosses can be advanced for further trials for developing superior yard long bean varieties.

The pot culture experiments done for screening Fusarium wilt resistant genotypes by artificial inoculation of pathogen revealed that treatments were highly significant. Least mortality was shown by the line P-1, tester TVM-1 and cross VS-86 x TVM-1 followed by Varuvila-2 x TVM-1 and P-1 x TVM-3.

Critical assessment of results suggests ample scope of improvement of yield and fusarium wilt resistance through selection based on combining ability and heterosis. Three superior crosses, VS-86 x TVM-1, P-1 x TVM-1 and Vellayani x TVM-1 were identified which were high yielding and reduced disease incidence. Among these VS-86 x TVM-1 was found to be most superior. Thus the work can be continued with these crosses for evolving varieties superior for yield and fusarium wilt disease resistance.