EVALUATION OF VEGETABLE COWPEA (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) FOR LEGUME POD BORER, *Maruca vitrata* (Fab.) RESISTANCE AND YIELD

BY

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DECLARATION

I hereby declare that this thesis entitled "Evaluation of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) for legume pod borer, *Maruca vitrata* (Fab.) resistance and yield" 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 "Evaluation of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) for legume pod borer, *Maruca vitrata* (Fab.) resistance and yield" is a record of research work done independently by Ms. Pournami R. Panicker 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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INTRODUCTION

1. INTRODUCTION

Vegetable cowpea, *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt, is a vegetable crop widely cultivated in Kerala. The escalating demand for its long green pods has resulted in round the year cultivation of the crop. Continuous cultivation, in turn, has aggravated the pest and disease problems. No doubt, vegetable cowpea crop receives frequent and heavy insecticide application to protect it from several insect pests. Legume pod borer, *Maruca vitrata* (Fab.) is one of the most prevalent and damaging among them. In a recent study on insecticide residues in vegetables collected from markets in Kerala, it was found that vegetable cowpea pods offered for sale contained high levels of insecticide residues (Anon, 1996). This can be attributed to the unscrupulous application of insecticides by vegetable cowpea growers.

Intensive use of insecticides, apart being costly, pose environmental and health hazards. Hence crop pest control tactics that reduce the dependence on insecticides are to be devised. Use of crop varieties even with moderate levels of plant resistance can substantially reduce insecticide use. Utilization of hostplant resistance in insect control is currently receiving more attention than ever before. With the realization of the importance of hostplant resistance in the Integrated Pest Management (IPM) systems, development of varieties that fit better in IPM programmes has become a severely felt need (Dent, 1995). Even partially resistant varieties that suffer lesser damage from insect attack than susceptible cultivars can be of immense value and can fit well into any IPM system. A low level of resistance not only reduces the viability of the pest but also favours the activity of natural enemies.

Legume pod borer is a pyralid moth infesting several leguminous crops including cowpea. The moth lays eggs on or near flower buds. The young caterpillar infests tender stem, flower bud or developing pod. Within the pod the caterpillar feeds on seeds and plug the entry points on pods with excreta. The infested flowers and pods may be webbed together. The flower and pod damages in vegetable cowpea consequent to legume pod borer attack lead to considerable yield losses.

Plant resistance to insect pests is often found in traditional varieties and unimproved germplasm (Saxena and Khan, 1991). Hence screening such varieties for resistance may turn out to be successful. Assessment of plant resistance through measurements of insect damages employing damage criteria reflecting the ultimate crop loss is a rational approach (Tingey, 1986). The field screening technique for screening cowpea for legume pod borer resistance developed by Jackai (1982) was based on flower, pod and seed damage parameters. This technique was employed in several subsequent legume pod borer screening programmes.

Identification of morphological and biochemical plant characters conferring resistance to insect pests is important in breeding for resistance. Several plant characters have been implicated in resistance of cowpea to legume pod borer (Singh, 1978; van Emden, 1989; Oghiakhe, 1992; Oghiakhe *et al.*, 1992 a)

Screening vegetable cowpea germplasm for legume pod borer resistance and understanding the mechanisms of resistance are the primary steps in any effort to develop high yielding varieties with desired levels of resistance. The research work done in this line is scanty.

In the above background, the present study aimed at screening vegetable cowpea cultivars for hostplant resistance to legume pod borer was taken up. Efforts were also made to identify morphological and biochemical bases of resistance. Selected partially resistant cultivars were subjected to yield evaluation as well.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study involved screening of vegetable cowpea germplasm for legume pod borer resistance and evaluation of selected partially resistant lines for vegetable pod yield. The literature pertinent to the study is organised and presented under different headings.

2.1 The crop

Vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt (Syn. *Vigna sesquipedalis* (L.) Fruw., *Vigna sinsensis* var. *sesquipedalis* (L.) Koern.) often referred in literature by the common name yard-long bean is a vegetable crop widely cultivated in India, Indonesia, Philippines and Sri Lanka (Chakraborti, 1986). Yard-long bean differs from the other two cultivated subspecies, (*unguiculata* and *cylindrica*) of *V. unguiculata* which are mainly grown as pulse crop, in growth habit and pod characters. Yard-long bean is a climbing annual with 30-90 cm long pendent pods which are fleshy and inflated when young but tending to shrink when dry (Purseglove, 1968). This crop with protracted flowering and fruiting phases is often severely damaged by flower thrips, aphids, pod borers and pod sucking bugs. Vegetable cowpea cultivated round the year in Kerala receives frequent and very heavy insecticide application to protect it from various pests. This is evident from the insecticide residue studies conducted at the College of Agriculture, Vellayani on 54 vegetable cowpea pod samples collected from different vegetable markets in Kerala (Anon, 1996). These studies revealed insecticide contamination in all the samples and organophosphate residue above maximum residue limit (MRL) in about 45 per cent of them, the highest level detected being seven times that of MRL.

2.2 The pest

Legume pod borer, *Maruca vitrata* (Fab.) (Syn. *Maruca testulalis*, Geyer) (Lepidoptera : Pyralidae) is a highly damaging post flowering pest of several leguminous crops including cowpea (Jackai and Adalla, 1997). The crop loss caused by the pest is tremendous since the larvae feed on flowers and developing pods.

It is a polyphagous borer with a wide host range surpassing the limits of leguminosae family. Attachi and Djihou (1994) found 22 host species distributed in eight families of which 77 percent are leguminous. *Cajanus cajan* (L.) Millsp. and *Vigna unguiculata* (L.) Walp. are two vulnerable species, the former being highly preferred for oviposition by the insect.

The pest which was of minor importance in southeast Asia earlier has become recently a major pest of legumes in the region (Tamo *et al.*, 1997). Bottenberg *et al.* (1997) identified the amount and distribution of rainfall, relative humidity and temperature as the key factors influencing the population levels of the pest. Legume pod borer develops and reproduces better under high relative humidity and moderate temperature while population density tends to be lower in drier weather (Jackai *et al.*, 1990).

The moth lays eggs on the flowers, flower buds and young pods. The eggs hatch within 2-3 days and the first instar larvae start feeding at the oviposition sites. It bores into the pods and devours the ripening seeds one after another. The larval burrow is marked by a mass of brownish excrement at the entrance of the gallery. After about 10 days the 5th instar larvae pupates. Pupal period is about a week (Anithakumari, 1992).

2.3 Hostplant resistance

Hostplant resistance refers to the inherent ability of plants that helps to protect them from damages caused by insects, the ultimate degree of damage being decided by the relative amount of heritable qualities possessed by the plant (Painter, 1951). It includes those characters that enable the plant to avoid or tolerate insect attack or recover from injury caused by insect attack (Snelling, 1941). The expression of genetic resistance, although influenced by the environment is not strictly under environemntal control (Kogan, 1994) in contrast to ecological resistance conferred by transitory environmental factors (Ananthakrishnan, 1992).

Reaction of hostplant to insect pest may vary from high level of resistance to extreme susceptibility. Hostplant resistance of a variety is definable only in terms of other and usually more susceptible varieties. A variety that suffers lesser attack or lesser crop loss in the event of comparable pest population can be considered partially resistant (Dent, 1995).

Categorization of plant resistance phenomena into non-preference, antibiosis and tolerance by Painter (1951) is extremely useful and still widely employed. Genetic resistance is often a combination of two or even all three of these phenomena (van Emden, 1989). Kogan and Ortman (1978) proposed the term 'antixenosis' to describe hostplant characteristics responsible for non-preference.

Non-preference is operative when a plant possesses characteristics that make it unattractive to insect pest for feeding, colonization or oviposition. Antixenosis may be governed by biochemical, anatomical and/or morphological factors of the hostplant. Russell (1978) emphasised the role of morphological features of the hostplant such as general size, shape and colour of the plant, leaf pubescence etc., and biochemical plant compounds which act as repellents to pest in deciding the level of non-preference resistance citing examples. Pubescence has been reported to interfere with oviposition and feeding by many insects (Gallun *et al.*, 1973; Pathak and Saxena, 1980; Benedict *et al.*, 1983; Ramaswamy, 1988). Oviposition of *Chilo suppressalis*, the striped moth borer is less on pubescent than glabrous rice varieties (Pathak, 1977). Thick and tough plant tissues present mechanical obstruction to feeding and oviposition. Level of resistance to jassids in cotton depends on the thickness of leaf and toughness of vascular tissues (Batra and Gupta, 1970). Lukefahr *et al.* (1971) found that glabrous strains of cotton are more resistant to *Helicoverpa zea* and *Heliothis virescens* than pubescent ones. Oviposition was less on glabrous cultivars. Jackai and Oghiakhe (1989) found pod wall trichomes to be a major factor for legume pod borer resistance in two accessions of wild cowpea, *Vigna vexillata*. Oghiakhe *et al.* (1992a) found pod trichome density to be important in reducing damage to cowpea pods by legume pod borer larvae and pointed out the possible role of trichomes in adversely affecting mobility and food consumption of the larvae.

Antibiosis refers to the adverse effects of feeding on a resistant hostplant on the survival, development and reproduction of insects. Antibiotic symptoms usually manifested include larval death in early instars, abnormal growth rate, failure to pupate, decreased fecundity and reduced fertility which may be attributed to host factors like presence of toxic metabolites, insufficiency or imbalances of essential nutrients and presence of antimetabolites, enzymes or other compounds adversely affecting food digestion and utilization (Kogan, 1994). Resistance to many insect pests of cotton is associated with high concentrations of a polyphenolic compound, gossypol, in plant tissues (Lukefahr and Houghtaling, 1969; Lukefahr and Martin, 1966). Combination of high square gossypol content with glaborus nature can result in as much as 60-80 per cent reduction in *Helicoverpa zea* and *Heliothis virescens* larval population (Kumar, 1984). Nutritionally related antibiotic effect was clearly demonstrated in studies with rice variety 'Mudgo' which is resistant to brown planthopper (Pathak, 1970). Young females feeding on 'Mudgo' plants had underdeveloped ovaries and contained few mature eggs. The symptom was ascribed to the reduced asparagine content of the resistant rice. Insect-plant interactions relating to allelochemic compounds and nutritional factors that interfere with digestion and food intake were reviewed by Ishaaya (1986). Manifestation of different antibiotic symptoms such as reduced larval survival, prolonged larval period, decreased fertility and low fecundity due to insect feeding on resistant plants have been reported by various workers (Lall and Sukhani, 1982; Ofuya and Akingbohunbe, 1986; Hammond and Cooper, 1989). High larval mortality of black cowpea moth, *Cydia ptychora* (Meyrick) was observed on resistant cowpea varieties by Ofuya and Akingbohunbe (1986). Antibiosis was manifested as extended nymphal duration and decreased survival of bean flower thrips *Megalurothrips sjostedti* (Trybom) in cowpea, *Vigna unguiculata* (L.) Walp., genotype TVX 3236 (Salifu *et al.*, 1988).

Tolerance refers to the capacity of certain plants to repair injury and grow to produce an adequate yield despite supporting an insect population at a level capable of damaging a more susceptible plant. It is generally attributed to plant vigour, regrowth of damaged tissues, resistance to lodging, production of additional branches or tillers and yield compensation through increased growth of other plants in plant communities (Kogan, 1994). Beck (1965) classified tolerance under pseudo-resistance viewing it as an adaptive mechanism for survival of the plant against herbivore pressure which is largely independent of herbivore response. Tolerance to various pests have been recorded from alfalfa, barley, cassava, cotton, rice, sorghum and wheat (Smith, 1989). Tolerance has no adverse effect on insects pests, nor do they provide any selection pressure on insects and hence can prevent the development of insect biotypes (Tingey, 1981). Highlighting the advantages of tolerance, Panda (1979) stressed its importance in pest management programmes.

2.3.1 Sources of resistance to insect pests

The sources of resistance genes available as a basis for conventional breeding programmes are varieties of the crop in question, wild types of the same species, compatible wild progenitors or close relatives available in germplasm banks. Most sources of resistance to insect pests have been found within the crop species itself and resistance derived from wild species has been exploited only in few crops (Russell, 1978). Resistance is often found in traditional varieties and unimproved germplasm (Saxena and Khan, 1991) and search within species is the foremost step. van Emden (1987) suggested that screening of commercial varieties should be done in the initial stage of search for resistance since partial resistance to the pest may be found in some varieties, eventhough this character was not purposely selected during the breeding programme. Partial resistance in an existing variety becomes immediately useful, particularly as part of an integrated pest management system. Resistance in an unadapted variety or wild relative calls for their transfer to commercial cultivars. Interspecifc and intergeneric resistance gene transfer endeavours were successful in several instances (Knight *et al.*, 1974; Everson and Gallun, 1980).

Genetic engineering of plants allows transfer of single genes to the target species from a wide variety of sources including higher and lower plants, bacteria and animals. This suggests the possibility of cutting across all barriers facing plant breeders in transferring genetic characters into a crop from unrelated plants immune to a particular pest (Levin, 1979; Harms, 1983). However, only a limited number of plant species are amenable to genetic engineering at the present state of the technology. Currently, conventional plant breeding offers the surest route to generate insect resistant crop varieties provided a suitable resistance source can be found (Gatehouse, 1991).

Sources of resistance to several important insect pests of cowpea could be located within the species itself. Screening of cowpea, *Vigna unguiculata* (L.) Walp., germplasm for pest resistance resulted in identification of lines/varieties resistant to spiny pod borer, *Etiella zinckenella* Tiet. (Bindra and Sagar, 1976), legume pod borer, *Maruce testulalis* (Geyer) (Singh, 1978), cowpea black moth, *Cydia ptychora* (Meyr.) (Perrin, 1978; Ezueh, 1981; Ezueh and Taylor, 1981), pod sucking bugs, *Riptortus dentipes* (Fab.) and *Anoplocnemis curvipes* (Fab.) (Khaemba, 1985) and cowpea aphid, *Aphis craccivora* Koch. (Sulochana and Peter, 1986).

Screening of cowpea, *Vigna unguiculata* (L.) Walp. germplasm for legume pod borer resistance at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria resulted in the identification of a resistant source employable in breeding porgrammes (IITA, 1981). Screening cowpea germplasm at IITA resulted in the identification of two resistant cultivars, viz., TVu 946 and TVu 4557 (Singh, 1978). Green house investigation by Macfoy *et al.* (1983) showed TVu 946 to be resistant.

2.3.2 Resistance evaluation and field screening techniques

A detailed account of the techniques for evaluating plant resistance to insects was provided by Tingey (1986). For field screening of germplasm and assessment of plant resistance, either laboratory reared or field collected test insect population can be released into field plots if natural infestation fails to develop at desired time or magnitude. Measurement of resistance can be accomplished by insect population/growth and development assessment or plant growth and damage assessment (Tingey, 1986).

The earliest attempt to develop a technique for field screening of cowpea for legume pod borer resistance was the one made by Wolley and

Evans (1979). The screening methodology evolved by Dabrowski *et al.* (1983) involves artificial infestation of plants with eggs in the pre-flowering period.

Insecticides with selective properties can be a powerful tool for conserving and enhancing target pest population (Tingey, 1986). The effectiveness of the technique depends on the availability of an insecticide the use of which at a specific dosage is relatively inactive against the target pest, but toxic to non-target speices including competing pests and natural enemies (Eveleens *et al.*, 1973; Shepard *et al.*, 1977). Successful screening of cowpea for legume pod borer resistance requires selective elimination of non-target pests like flower thrips, *Megalurothrips sjostedti* (Tryborn) and hemipteran pod bugs including *Riptortus* spp. and *Clavigralla* spp. to ensure that these non-target pests do not mask the effect of *M. vitrata* on the crop (Jackai, 1982). Monocrotophos is ineffective against legume pod borer at dose rates sufficient to control thrips and hemipteran pod-bugs (Jackai, 1983). Application of monocrotophos at low dose rate of 200 g a.i./ha to control non-target pests including leaf feeding beetles, aphids, thrips and pod sucking bugs is a standard practice in legume pod borer resistance studies on cowpea (Jackai and Singh, 1988; Oghiakhe *et al.*, 1992 a).

Assessment of plant resistance through measurements of insect damage should be made employing damage criteria closely associated with ultimate loss in crop yield and quality (Tingey, 1986). Studying several damage parameters for assessment of resistance of cowpea to legume pod borer, Jackai (1982) concluded that flower, pod and seed damage parameters provided the most important assessment and developed a field screening technique involving computation of overall plant resistance index based on different damage parameters. Several later studies on resistance of cowpea to legume pod borer employed this field screening technique (Oghiakhe, 1992; Oghiakhe *et al.*, 1992a; Oghiakhe *et al.*, 1993). For initial screening of large collection of genotypes Oghiakhe *et al.* (1992 b) developed a rapid visual field screening technique which involves only measurement of flower and / or pod damage.

2.3.3 Role of plant characters in hostplant resistance

Discernment of morphological and biochemical plant factors conferring resistance to insect pests is important in breeding for resistance. Morphological bases of resistance include factors such as colour and shape of plant that influence orientation of pest towards the plant, presence or absence of pubescence and type of cuticle waxes that affect oviposition, locomotion or feeding by insects, tissue toughness that influence feeding and such other characters that impede host finding and / or utilization by insect pests. Biochemical bases are plant chemicals that modify insect behaviour (attractants, arrestants, stimulants, repellants and deterrents) or affect insect physiology (nutrients, physiological inhibitors and toxicants) (Hsiao, 1969). Several plant characters have been implicated in resistance of cowpea to legume pod borer.

2.3.3.1 Pubescence

Pubescence has been reported as an insect resistance trait interfering with oviposition and feeding by insects in several crops (Lukefahr *et al.*, 1965; Gallun *et al.*, 1973; Pathak and Saxena, 1980; Benedict *et al.*, 1983;

Ramaswamy, 1988). Resistance due to pubescence in 17 crops against 32 pest species was reported by Webster (1975). However, there are also reports of increased susceptibility due to pubescence (Southwood, 1986; Navasero and Ramaswamy, 1991). Webster (1975) reported increased susceptibility in five crops to 13 pest species due to pubescence.

Pubescence on plant surfaces is made up of individual trichomes or hairs. When pubescence is present, the mechanism of resistance may depend upon one or more of four characteristics of trichomes, their density, errectness, length and shape. Moreover, some trichomes also possess glands, the exudates of which confer resistance against some insects (Dent, 1991).

The role of trichomes in resistance to some pests has been reported in cowpea and other leguminous species. Resistance to *Clavigralla tomentosicollis* and *Maruca testulalis* in wild cowpea, *Vigna vexillata* (Acc. TVNu 72) has been shown to be due to pod wall trichomes (Chiang and Singh, 1988; Jackai and Oghiakhe, 1989). Oghiakhe *et al.* (1992 a) found negative and significant correlation between pod wall trichome density and pod damage by legume pod borer in cowpea, *Vigna unguiculata* and highlighted the role of trichome density in reducing pod damage. But the length of non-glandular trichomes on pods was found to have no relationship with pod infestation and damage. They stressed the importance of angle of insertion of non-glandular trichomes. Errect trichomes are less likely to injure larvae in their movement on pods.

2.3.3.2 Pod wall toughness

Chiang and Jackai (1988) found pod wall toughness to be important in contributing to pod resistance in cowpea to pod sucking bugs. Oghiakhe *et al.* (1992 c) measured pod wall toughness of cowpea varieties with differing levels of resistance to legume pod borer and found that there was no relationship between pod damage and pod wall toughness.

2.3.3.3 Other morphological characters

Distribution of *M. vitrata* larvae is closely related to the distribution of reproductive structures which serve as the larval feeding sites and hence plant architecture is important in deciding the extent of damage. Cowpea varieties with upright and long peduncles that hold pods away from the canopy as well as from each other suffer less damage by legume pod borer (Singh, 1978). Oghiakhe *et al.* (1991) found that *V. unguiculata* cultivars with pods held within the leaf canopy suffered significantly more damage than cultivars with pods held above the canopy. van Emden (1989) attributed the resistance in cowpea varieties with long peduncles and those which hold pods widely apart on the peduncle to reduced accessibility of the larvae of the borer to pods to further pod infestation. The larvae penetrate the pods more successfully when pods are in contact with each other or the foliage. Oghiakhe *et al.* (1992 d) also observed reduction in pod damage caused by *M. vitrata* in cowpea varieties with wide pod angle.

Khaemba (1985) identified peduncle length as a factor determining the extent of damage in cowpea due to pod sucking bugs, *Riptortus dentipes* (Fab.) and *Anoplocnemis curvipes* (Fab.).

2.3.3.4 Biochemical factors

A wide array of chemical substances including inorganic chemicals, primary and intermediary metabolites and secondary substances are known to impart resistance to a wide variety of insect pests (Norris and Kogan, 1980). Hostplant deficient in certain nutritional elements required by the insect pest may prove to be resistant. Macfoy *et al.* (1983) in their studies on biochemical mechanism of resistance in cowpea cultivars to legume pod borer, *M. testulalis* (Geyer) revealed that the levels of both total sugars and total aminoacids were quantitatively lower in resistant than in susceptible varieties.

A wide range of allelochemic compounds are present in plants and play important defensive roles against insects (Norris and Kogan, 1980). The defensive chemicals influence the behavioural and / or physiological responses of insects (Dent, 1991). Levin (1971) suggested that one of the most important groups of secondary plant compounds playing a defensive role against insect pests are phenolics. Phenolics occur in most plant species and several associations have been reported between phenolic compounds and resistance of plants to insect damage (Lukefahr and Houghtaling, 1969; Todd *et al.*, 1971; Leszezynski *et al.*, 1985).

Oghiakhe *et al.* (1993), determined phenolic content in cowpea cultivars with variable levels of resistance to legume pod borer. Phenol content in flowers and pods varied considerably between cultivars. Despite the differences in phenol concentration among cultivars, correlation between phenol content and resistance parameters did not indicate any significant role of phenol in resistance to legume pod borer. The absence of feeding deterrents and repellents to *M. testulalis* in cowpea flower was earlier observed by Okech and Saxena (1990).

Oghiakhe (1992) studied the relationship between leaf chlorophyll and cowpea resistance to legume pod borer and found that high chlorophyll content in leaves is associated with increased susceptibility. The observed high correlation between total leaf chlorophyll and susceptibility prompted him to suggest that determination of total leaf chlorophyll content would enable classification of cultivars for resistance / susceptibility to *Maruca testulalis*.

2.4 Vegetable pod yield and its components

The literature relating to the studies in vegetable cowpea on yield and component characters are reviewed hereunder.

2.4.1 Genetic variability, heritability and genetic advance

The pre-requisite for any breeding programme is the availability of an array of diverse genotypes. The larger the variability, the better is the chance of identifying superior genotypes. Study of variability enables the breeder to determine the crop breeding strategies. Only genetically determined variation can be utilized for crop improvement. Superior genotypes can be successfully selected only when the major part of the variability of the trait is genetic. The extent of variability is studied by working out genotypic and phenotypic coefficients of variation.

Variability studies in eleven cowpea varieties by Jana *et al.* (1982) revealed high genotypic coefficient of variation for vegetable yield and pods/plant. Heritability and genetic advance were high for the characters 1000-grain weight and days to flower.

Ye and Zhang (1987) reported high heritability for pod length, flowering date and length of flowering period in cowpea.

Significant differences among 31 genotypes of cowpea for different characters were observed by Sobha (1994). Vegetable yield, pod weight and number and pods per kg had high genotypic coefficient of variation. High heritability and genetic advance were observed for days to harvest, pod length, pod girth, pod weight and vegetable yield.

Sreekumar *et al.* (1996) studied 18 vegetable cowpea genotypes and obtained the highest GCV for green pod yield (45.06) followed by pod length (43.99). The relative magnitude of differences between phenotypic coefficient of variation and genotypic coefficient of variation was low for characters such as days to flower, days to first picking, pod length and seeds per pod indicating low degree of environmental influence on these characters. But this difference was high for characters like number of fruiting points, pods per plant and yield of green pods indicating the high influence of environment on these characters. Pod length had the highest heritability value, followed by number of days to first picking, number of seeds per pod and days to flower. High genetic advance was obtained for pod length and number of seeds per pod.

Resmi (1998) studied 30 different genotypes of yard long bean. The analysis of variance revealed significant differences among the genotypes for all the 24 characters studied. The maximum PCV was recorded for pod yield per plant (30.56) followed by number of pods per kg (26.54) and number of inflorescence per plant (25.16). The highest genotypic coefficient of variation was obtained for pod yield per plant (29.50) followed by number of pods per kg (26.50). Heritability was highest for number of pods per kg (0.98) and 100-seed weight (0.98) followed by pod weight (0.96) and pod length (0.95).

High heritability along with high genetic advance is indicative of additive genetic variance (Johnson *et al.*, 1955). Resmi (1998) observed high heritability and genetic advance for pod yield per plant, number of pods per kg, number of inflorescences per plant and weight of pods. Among other characters with high heritability, genetic advance was moderate for vine length, pod girth and 100-seed weight but low for days to first flowering, days to first harvest and pod length.

2.4.2 Correlation studies

Yield is a complex character determined by many component characters. Selection for a specific character results in correlated response for some other characters. Interrelationship between vegetable pod yield and its contributing characters have been reported by many workers in cowpea.

Kumar *et al.* (1976) reported positive correlation of pod yield with branches per plant, pod length, pod thickness, days to flowering and days to maturity.

Jana *et al.* (1982) observed positive correlation of pod yield with number of primary branches per plant. But primary branches was negatively correlated with pod length and days to flower.

Sharma *et al.* (1988) reported that green pod yield was positively and highly correlated with pods per plant, days to first flowering, seeds per pod and plant height.

High positive correlation was observed between pod yield and days to harvest, pod length, pod girth, pod weight, pods per kg, seeds per pod and 100-seed weight in cowpea (Sobha, 1994).

Sreekumar *et al.* (1996) reported significant positive correlation of yield of green pods with number of pods per plant, pod length and number of seeds per pod, both at phenotypic and genotypic levels. The number of fruiting points per plant also had positive significant association with yield of green pods. Number of pods per plant was correlated positively with number of fruiting points per plant and negatively with number of days to first flowering as well as first picking. Number of seeds per pod showed significant positive correlation with pod length and number of days to flower. They suggested the use of characters like number of fruiting points, number of pods/plant, pod length and number of seeds per pod as selection criteria for yield improvement in vegetable cowpea in view of their high positive correlation with green pod yield.

Correlation studies by Resmi (1998) indicated high positive correlation of pod yield with weight and length of pods as well as number of pods per plant.

2.4.3 Path analysis

The concept of path coefficient analysis was developed by Wright (1921). After the demonstration of its use in plant breeding by Dewey and Lu (1959) this analysis has been widely employed for elucidation of correlation between plant characters.

Murthy (1982) observed number of pods per plant as the major contributor to yield followed by pod length, seeds per pod and pod weight.

High positive direct effect of number of pods per plant and number of pods per inflorescence on vegetable cowpea pod yield was reported by Jana *et al.* (1982). Ye and Zhang (1987) indicated number of pods per inflorescence as the character exerting greatest direct effect on pod yield.

Biradar *et al.* (1991) found that pod weight had the highest positive direct effect on yield. Pod length, pods per plants and seeds per pod showed negative direct effect on yield. Pod weight per plant could be used as reliable parameter for yield in cowpea.

Sobha (1994) found that pod weight exerted the maximum direct positive effect on yield followed by pod girth and 100-seed weight in cowpea.

Resmi (1998) reported that number of pods per plant exerted the maximum positive direct effect on pod yield followed by pod weight in vegetable cowpea. Length of pods exerted positive indirect effect on pod yield through weight of pods and number of pods per kg while weight of pods exerted indirect effect through number of pods per kg. Number of pods per kg had negative direct effect on pod yield along with its indirect effect through weight of pods and length of lateral leaflet.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study for the evaluation of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) for legume pod borer, *Maruca vitrata* (Fab.) resistance and yield was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 1997-1999.

The data for the investigations were collected from two field experiments. Experiment I was aimed at screening vegetable cowpea germplasms for legume pod borer resistance. The partially resistant accessions, so identified were evaluated in Experiment II for yield and yield component characters.

3.1 Experiment I : Field screening for legume pod borer resistance

3.1.1 Materials

The materials for the study comprised of 50 local cultivars collected from different areas of cultivation in Kerala and an improved variety, Sharika of vegetable cowpea. The test entries are designated by accession numbers Vs 1 to Vs 51. The source or place of collection of test entries are provided in Table 1.

Table 1 List of vegetable cowpea accessions used for the study and their sources

Acc. No.	Source
Vs 1.	Vellayani, Thiruvananthapuram Dist.
Vs 2.	Kakkamoola, Thiruvananthapuram Dist.
Vs 3.	Koliyoor, Thiruvananthapuram Dist.
Vs 4.	Venganoor, Thiruvananthapuram Dist.
Vs 5.	KHDP
Vs 6.	Vakathanam, Kottayam Dist.
Vs 7.	Kottukal, Thiruvananthapuram Dist.
Vs 8.	Velloor, Kottayam Dist.
Vs 9.	Ettumanoor, Kottayam Dist.
Vs 10.	Ponakam, Alappuzha Dist.
Vs 11.	Eeera, Kottayam Dist.
Vs 12.	Perunna, Kottayam Dist.
Vs 13.	Thekkekkara, Alappuzha Dist.
Vs 14.	Chingavanam, Kottayam Dist.
Vs 15.	Kunnamkulam, Thrissur Dist.
Vs 16.	Thalavady, Alappuzha Dist.
Vs 17.	Kavumbhagom, Pathanamthitta Dist.
Vs 18.	Mayoor, Kottayam Dist.
Vs 19.	Kilikolloor, Kollam Dist.
Vs 20.	Venganoor, Thiruvananthapuram Dist.
Vs 21.	Vallikkezhu, Kollam Dist.
Vs 22.	Neerettupuram, Pathanamthitta Dist.
Vs 23.	Sharika, Kerala Agricultural University
Vs 24.	KHDP
Vs 25.	Kundara, Kollam Dist.
Vs 26.	Paliakkara, Pathanamthitta Dist.
Vs 27.	Kanakkari, Kottayam Dist.
Vs 28.	Guruvayoor, Thrissur Dist.

Acc. No.	Source
Vs 29.	Puthupally, Kottayam Dist.
Vs 30.	Pullikanaku, Kollam Dist.
Vs 31.	Punnamoodu, Alappuzha Dist.
Vs 32.	Karimulakkal, Alappuzha Dist.
Vs 33.	KHDP
Vs 34.	KHDP
Vs 35.	KHDP
Vs 36.	KHDP
Vs 37.	Thuruthi, Kottayam Dist.
Vs 38.	Adoor, Pathanamthitta Dist.
Vs 39.	Nedumudi, Alappuzha Dist.
Vs 40.	Kumarakom, Kottayam
Vs 41.	Balaramapuram, Thiruvananthapuram Dist.
Vs 42.	Kolanchery, Eranakulam Dist.
Vs 43.	Kezhekkambalam, Eranakulam Dist.
Vs 44.	Puthiakavu, Alappuzha Dist.
Vs 45.	Oolaketty, Alappuzha Dist.
Vs 46.	KHDP
Vs 47.	Thrikkodithanam, Kottayam Dist.
Vs 48.	Thonnakkal, Alappuzha Dist.
Vs 49.	Aanaprambal, Alappuzha Dist.
Vs 50.	Vazhapally, Kottayam Dist.
Vs 51.	Karukachal, Kottayam Dist.

3.1.2 Methods

3.1.2.1 Layout and conduct of experiment

In experiment I, 51 test entries were evaluated for pod borer resistance in a randomised block design with two replications. The land was well prepared incorporating farmyard manure @ 20 t per ha. The entire field was divided into two blocks of fifty one plots each. Treatments were allotted to plots in each block at random. Each plot consisted of 3 rows, 2.1 m long. Spacing was 1.0 m between rows and 0.3 m between plants in a row. Fertilizers were applied @ 10 kg N, 30 kg P_2O_5 and 10 kg K_2O per ha as basal dressing and 10 kg N per ha two weeks after sowing.

The experimental crop was raised during the period November 1997 to February 1998. This season was deliberately chosen since the natural incidence of the target pest usually peaks during the period. One week prior to planting, a susceptible local cultivar of cowpea, grown for grain was planted along the borders of the field to serve as multiplication foci for the test insect, *Maruca vitrata* (Plate 1). Further, release of larvae to experimental plot was employed to enhance the level of infestation. Larvae of *M. vitrata* at the stage of second instar were collected in large numbers from infested cowpea fields and released in the experimental plot at the rate of 2 larvae per plant at early flowering phase of crop (50 days after planting). Monocrotophos (as Nurvacron 40 EC) was sprayed twice, at initial flowering phase and early podding stage, @ 200 g a.i. per ha to control aphids, flower thrips and pod sucking bugs. This was to ensure that the population of these non-target pests do not build up to mask the effect of *M. vitrata* on the crop. Application of monocrotophos at the above rate at weekly intervals starting from 14 days after planting can be employed in plant resistance studies on *M. vitrata* (Jackai and Singh, 1988). Jackai (1983) has shown that monocrotophos was ineffective in controlling *M. vitrata* at the rate of application used in this experiment. Plants were trailed on coir ropes tied between wooden standards erected 70 cm apart along the rows of plants.

Plate 1 : Field with boarder row of susceptible grain cowpea cultivar to build up the pest population

3.1.2.2 Data collection

Different damage parameters were measured employing the field screening technique developed by Jackai (1982) as detailed below :

a. Number of larvae per 25 flowers

(Severity of larval infestation of flowers)

This was determined by randomly collecting 25 flowers 10 weeks after planting from each plot. The samples were collected in vials containing 30 per cent alcohol and subsequently examined for larval counts.

b. Percentage infestation of pods

Twenty pods at vegetable maturity stage were harvested at peak podding phase from each plot. Each sample was examined in the laboratory to determine the number of pods with entry / exit holes made by *M. vitrata*. Pod infestation was expressed as a percentage of total number of pods collected from each plot.

c. Pod damage severity

Pod samples used for the assessment of percentage pod infestation were examined for the number of larval entry / exit points. The results were expressed as the number of holes per pod.

d. Seed damage assessment

The sample used for assessing pod infestation was also used for assessing seed damage measurements. A seed damage index (Isd) was worked out using the following formula.

$$I_{sd} = \frac{ds \times 100}{pt}$$

where ds = number of damaged seeds

pt = number of pods sampled

e. Plant resistance index (Ipr)

This was computed for each variety using a combination of the three damage parameters.

Number of larvae per 25 flowers

Percentage pod infestation

Seed damage index (I_{sd})

$$I_{pr} = \frac{W_1 S + W_2 T + W_3 M}{W_1 + W_2 + W_3}$$

where S, T, M are measurements of damage of seed (S), pods (T) and flowers (M) respectively with weights W_1, W_2 and W_3. These weighted measurements reflect the relative importance attached to each.

Data on the following plant characters were obtained as detailed below.

a. Pod length : Pod length was measured using ten pods collected at random at vegetable maturity stage from each of the plots.

b. Pod width : Five pods at vegetable maturity stage were randomly selected from each plot. Each pod was cut across through a developing seed. The distance between the pod wall sutures in the cross section was measured to obtain pod width and the mean value was worked out.

c. Peduncle length : Length of fully elongated peduncle of ten randomly selected mature inflorescences from each plot was measured.

d. Non-glandular trichome density on pods

Five pods at vegetable maturity stage (eight days after flowering) were taken from each plot at random. The skin was peeled from the middle portion of the pods and observed under a compound microscope with a magnification of 100 x. The number of non-glandular trichomes observed in a microscopic field was counted. The non-glandular type of trichome consists of single, long cell with enlarged base which tapers towards the distal portion to form a narrow needle like filiform top. The area of the microscopic field was calculated using occular micrometer. Mean value of non-glandular trichome counts per mm^2 area of pod wall surface was calculated and expressed as non-glandular trichome density on pods.

e. Leaf chlorophyll content

Chlorophyll was estimated at about 70 DAP. The fully expanded leaf collected from the top was taken. 1 gram of fresh leaf sample was weighed out into a clean mortar. The tissue was ground to a fine pulp with the addition of 20 ml of 80 per cent acetone. The extract was centrifuged at 5000 rpm for 5 min. and the supernatant was transferred to a 100 ml volumetric flask. The residue also was ground with another 20 ml of 80 per cent acetone, centrifuged and the supernatant was transferred to volumetric flask. This process was continued until the residue became colourless. The mortar and pestle was also volumetric flask was made up with acetone. The absorbance of the extract was read in a UV-VIS spectrophotometer, systronics - 118 at 645 and 663 nm against 80 per cent acetone reagent blank.

Total chlorophyll content was separately worked out using the following equation.

$$\text{Total chlorophyll in mg per g tissue} = 20.2\ (A_{645}) + 8.02\ (A_{663})\ \times \frac{V}{1000 \times W}$$

A - absorbance at specific wavelength

V - final volume of chlorophyll extract in 80 per cent acetone

W - fresh weight of tissue extracted

3.1.2.3 Statistical procedure

The data on damage parameters, plant resistance index computed on the basis of damage parameters and the plant characters mentioned were subjected to analysis of variance (ANOVA) for varietal differentiation. Data on larval count and percentage pod infestation were subjected to square root and angular transformations respectively to satisfy the basic assumptions in ANOVA.

A correlation analysis was done to determine the degree of association between the different damage parameters. Correlations of damage parameters with pod characters (non-glandular trichome density on pods, pod width) and peduncle length were worked out.

3.2 Experiment II : Evaluation of partially resistant accessions for yield and yield component characters.

3.2.1 Materials

The material for this experiment comprised of 15 accessions selected from first experiment based on the plànt resistance index values.

3.2.2 Methods

3.2.2.1 Layout and conduct of experiment

The 15 accessions were planted in RBD with 3 replications. Land preparation and application of manures and fertilizers were done as in Experiment I. The entire field was divided into 3 blocks of 15 plots each and the treatments were allotted to plots in each block at random. Each plot of size 6 m x 3 m consisted of three rows of 6 m length. Spacing was 1.0 m between rows and 0.6 m between plants in a row. The experiment was conducted during March to July 1999, adopting recommended plant protection measures. The plants were individually trailed on coir ropes tied between standards / poles erected 60 m apart along the rows of plants.

3.2.2.2 Data collection

Data on the following characters were obtained from observations recorded on five randomly selected observation plants from each plot and working out the mean values.

a. Days to first flowering

b. Days to first harvest

c. Length of harvesting period

d. Number of pods per plant

e. Yield of vegetable pods per plant (g)

f. Number of inflorescences per plant

g. Length of main stem (cm)

h. Number of primary branches per plant

The pod characters viz., pod length (cm) pod girth (mm), pod weight (g) and number of seeds/pod were recorded from 10 randomly selected pods at the vegetable maturity stage from observational plants in each plot and mean value for each character was worked out.

Number of pods per inflorescence and length of peduncle were also worked out from a sample of 10 randomly selected inflorescences from observational plants in each plot. The pods on individual inflorescence were counted, peduncle length measured and the mean values were worked out.

The experimental plots were periodically observed for the incidence of pests and diseases.

3.2.2.3 Statistical analyses

Data from Experiment II was subjected to the following statistical analyses.

Analysis of variance and covariance

Variance and covariance analysis was done

a) to test the significance of differences among the genotypes with respect to various traits and

b) to estimate the variance components and other genetic parameters like correlation coefficients, heritability coefficient and genetic advance (Dabholkar, 1988).

3.2.2.3.1 Variance

	X	Y
Environmental variance (σ^2_e)	$\sigma^2_{ex} = E_{xx}$	$\sigma^2_{ey} = E_{yy}$
Genotypic variance (σ^2_g)	$\sigma^2_{gx} = \dfrac{G_{xx} - E_{xx}}{r}$	$\sigma^2_{gy} = \dfrac{G_{yy} - E_{yy}}{r}$
Phenotypic variance (σ^2_p)	$\sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$	$\sigma^2_{py} = \sigma^2_{gy} + \sigma^2_{ey}$

3.2.2.3.2 Coefficient of variation

Phenotypic and genotypic coefficient of variation (PCV and GCV) were estimated as

$$GCV = \frac{\sigma_{gx}}{\bar{x}} \times 100 \text{ and}$$

$$PCV = \frac{\sigma_{px}}{\bar{x}} \times 100$$

Where σ^2_{gx} - genotypic standard deviation

σ^2_{px} - phenotypic standard deviation

and $\bar{x}$ is the mean of the character under study.

3.2.2.3.3 Heritability (Broad sense)

$$H^2 = \frac{\sigma^2_g}{\sigma^2_p}$$

Where H^2 is the heritability (Jain, 1983)

3.2.2.3.4 Genetic advance as percentage of mean

$$GA = \frac{KH^2 \sigma_p}{\overline{X}} \times 100$$

Where K is the standardised selection differential. K = 2.06 at 5 per cent selection intensity (Miller *et al.*, 1958).

3.2.2.3.5 Correlation

$$\text{Genotypic correlation } (r_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation } (r_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{ey}}$$

3.2.2.3.6 Path analysis

Path analysis splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variable.

RESULTS

4. RESULTS

The results of the present investigation are presented under two major headings.

(i) Screening for legume pod borer resistance and

(ii) Yield evaluation of partially resistant cultivars

4.1 Screening for legume pod borer resistance

High intensity of legume pod borer infestation was observed in the experimental field as evidenced by the occurrence of extensive flower and pod damages. Without exception, *M. vitrata* larvae were observed in flowers of all the test entries (Plate 2). Infested flowers could be easily recognised by the presence of larval entry - exit holes on floral parts. Plate 3 shows the typical damage caused to peduncles. Webbing together of leaves and pods or developing pods on a peduncle is usually observed (Plates 4 and 5). Larval entry - exit holes would be present on infested pods (Plate 6). The larval entry points on pods are often covered with brownish frass (Plate 7).

4.1.1 Damage parameters and resistance evaluation

The legume pod borer damage parameters viz., number of larvae per 25 flowers, percentage pod infestation and seed damage index as well as the overall plant resistance index (Ipr) based on these parameters relating to 51 vegetable cowpea cultivars are presented in Table 2. Pod damage severity i.e., pod damage assessed as the number of larval entry - exit holes per pod is also given in this table.

Table 2 Legume pod borer damage measurements and plant resistance indices of 51 vegetable cowpea cultivars

Acc. No.	No. of larvae per 25 flowers (a)	Percentage pod infestation (b)	Pod damage severity	Seed damage index	Ipr (c)
Vs 1	40 (6.33)	65.08 (53.76)	1.10	100	58.33 (25)
Vs 2	45 (6.71)	24.83 (29.88)	0.35	50	39.17 (3)
Vs 3	32 (5.70)	70.00 (56.77)	1.85	110	57.92 (23)
Vs 4	40 (6.32)	70.00 (56.77)	2.05	160	70.00 (35)
Vs 5	25 (4.97)	70.50 (57.08)	1.60	130	57.50 (22)
Vs 6	27 (5.24)	60.00 (50.75)	1.40	120	53.75 (16)
Vs 7	25 (4.99)	65.08 (53.76)	1.65	60	44.17 (9)
Vs 8	21 (4.61)	50.00 (44.98)	1.10	75	39.79 (4)
Vs 9	43 (6.52)	81.03 (64.15)	1.30	40	54.58 (17)
Vs 10	21 (4.61)	55.03 (47.87)	0.75	90	43.96 (8)
Vs 11	23 (4.74)	70.00 (56.77)	2.35	155	60.42 (27)
Vs 12	20 (4.47)	75.17 (60.09)	2.15	160	61.67 (28)
Vs 13	38 (6.12)	75.17 (60.09)	1.55	15	46.25 (10)
Vs 14	29 (5.36)	80.00 (69.36)	1.70	65	51.88 (15)
Vs 15	40 (6.32)	75.17 (60.09)	0.95	100	61.67 (29)
Vs 16	36 (6.02)	75.17 (60.09)	1.30	90	58.12 (24)
Vs 17	51 (7.16)	87.61 (69.36)	2.20	200	88.13 (47)
Vs 18	52 (7.24)	75.17 (60.09)	3.05	230	89.58 (48)
Vs 19	34 (5.85)	29.50 (32.89)	0.70	90	42.50 (6)
Vs 20	27 (5.24)	60.00 (50.75)	1.20	195	66.25 (25)
Vs 21	38 (6.13)	39.78 (39.09)	0.90	105	49.71 (13)
Vs 22	49 (6.98)	94.74 (76.70)	1.80	330	109.37 (51)
Vs 23	40 (6.36)	60.22 (50.87)	1.30	130	62.29 (31)
Vs 24	24 (4.87)	39.78 (39.09)	1.10	135	47.71 (11)
Vs 25	31 (5.59)	75.17 (60.09)	1.40	255	83.75 (44)
Vs 26	38 (6.20)	85.36 (67.47)	2.35	240	87.71 (46)
Vs 27	16 (4.00)	55.03 (47.86)	0.95	40	33.13 (1)
Vs 28	36 (6.01)	24.83 (29.88)	0.35	50	34.79 (2)

Table 2 Contd.....

Acc. No.	No. of larvae per 25 flowers	Percentage pod infestation	Pod damage severity	Seed damage index	Ipr (c)
Vs 29	41 (6.40)	50.00 (44.98)	0.75	80	50.62 (14)
Vs 30	60 (7.75)	44.97 (42.10)	0.55	35	55.00 (18)
Vs 31	50 (7.07)	34.92 (36.21)	0.75	25	40.83 (5)
Vs 32	49 (6.98)	50.00 (44.98)	0.80	85	55.21 (19)
Vs 33	63 (7.91)	50.00 (44.98)	0.75	140	71.25 (37)
Vs 34	45 (6.71)	80.00 (63.41)	2.15	120	69.17 (34)
Vs 35	39 (6.22)	44.97 (42.10)	0.95	55	43.54 (7)
Vs 36	45 (6.71)	75.17 (60.09)	1.75	130	69.17 (33)
Vs 37	48 (6.89)	65.08 (53.76)	1.40	210	80.42 (42)
Vs 38	33 (5.70)	75.17 (60.09)	1.75	90	56.25 (20)
Vs 39	32 (5.65)	80.00 (63.41)	1.40	115	61.78 (30)
Vs 40	23 (4.74)	55.03 (47.87)	0.80	110	47.91 (12)
Vs 41	19 (4.33)	94.74 (76.70)	2.55	230	77.71 (40)
Vs 42	30 (5.46)	94.74 (76.70)	1.95	270	90.00 (49)
Vs 43	43 (6.52)	75.17 (60.09)	2.00	220	82.92 (43)
Vs 44	29 (5.36)	80.00 (63.41)	2.30	105	58.54 (26)
Vs 45	49 (6.52)	94.74 (76.70)	1.90	165	78.75 (41)
Vs 46	30 (5.47)	90.00 (71.54)	3.05	320	98.34 (50)
Vs 47	29 (5.36)	94.74 (76.70)	2.15	185	75.21 (38)
Vs 48	49 (6.98)	97.44 (80.77)	1.90	180	86.04 (45)
Vs 49	44 (6.61)	75.17 (60.09)	1.60	145	71.00 (36)
Vs 50	46 (6.80)	55.03 (47.87)	1.00	95	57.29 (21)
Vs 51	25 (5.00)	99.99 (90.00)	2.45	180	75.80 (39)
$F_{50,50}$	8.77**	6.14**	25.30**	12.41**	15.63**
$CD_{0.05}$	0.882	15.385	0.373	59.826	12.568
CV (%)	7.38	13.53	12.30	22.29	9.95

** Significant at 1 per cent level

Values in parentheses are :

(a.) Square root - transformed values

(b.) Angular - transformed values

(c.) Rankings of the entries

Plate 2 : *Maruca vitrata* larva inside a cowpea flower

Plate 3 : Typical damage symptom on peduncle

Plate 4 : Webbing together of pod and leaf

Plate 5 : Webbing together of pods on a peduncle

Plate 6 : Larval entry-exit holes on infested pods

Plate 7 : Entry holes on pods plugged with excreta

There were significant differences among the cultivars in the number of larvae per 25 flowers. Flower infestation was highest for Vs 33 for which the mean larval count from 25 flowers was as high as 63. The test entries statistically on par with Vs 33 with respect to flower damage were Vs 30, Vs 18, Vs 17 and Vs 31. The extent of flower damage was least for Vs 27 with 16.00 larvae per 25 flowers and was on par with seven other varieties. Those varieties with low extent of flower damage were Vs 41, Vs 12, Vs 8, Vs 10, Vs 11, Vs 24 and Vs 40. It is worthy to note that the flower infestation was nearly four times in the worst affected cultivar as compared to the least affected one.

Pod damage assessment was done employing two different criteria i.e., percentage pod infestation and pod damage severity, the later being assessed as the number of larval entry/exit holes per pod. Percentage pod infestation showed significant differences among cultivars. The values ranged from 25 (Vs 28 and Vs 2) to 100 (Vs 51). The cultivars statistically on par with Vs 2 and Vs 28 in pod infestation percentage were Vs 8, Vs 19, Vs 21, Vs 24, Vs 29, Vs 30, Vs 31, Vs 32, Vs 33 and Vs 35. Apart from Vs 51, high degree of pod infestation occurred in six other cultivars, viz., Vs 22, Vs 41, Vs 42, Vs 45, Vs 47 and Vs 48. Pod damage severity was least for Vs 2 and Vs 28 (0.35) which were also the cultivars with lowest pod infestation. Vs 30 and Vs 19 were the other cultivars with statistically equivalent low pod damage severity. Most severe pod damage was observed for Vs 46 and Vs 18. The pod damage severity assessment gave the value of 3.05 for both these cultivars and no other cultivar was statistically on par with them. Plates 8 and 9 show

infected pods from a few cultivars and a sample of larvae at different instars obtained from infested pods respectively.

The data on seed damage index (Table 2) showed significant differences among cultivars. Vs 13 and Vs 22 had the lowest (15) and highest (330) seed damage index values respectively. Cultivars with seed damage index values not significantly different from Vs 13 included Vs 2, Vs 7, Vs 9, Vs 14, Vs 27, Vs 28, Vs 30, Vs 31 and Vs 35. On the other hand, only Vs 46 had seed damage high enough to be statistically on par with Vs 22.

There were significant differences among cultivars in plant resistance index (Ipr) computed using a combination of the flower, pod and seed damage parameters. The Ipr values ranged from 33.13 to 109.37. Lower Ipr values indicate higher level of plant resistance. Vs 27 with the lowest Ipr value was identified as the most resistant among the 51 cultivars. Varieties not significantly different from Vs 27 were Vs 2, Vs 7, Vs 8, Vs 10, Vs 19, Vs 28, Vs 31 and Vs 35. The most susceptible variety was Vs 22 with an Ipr value of 109.37. Vs 46 was the only other cultivar with Ipr value on par with that of Vs 22.

4.1.2 Correlations among parameters of damage

The correlations among the different parameters for the assessment of legume pod borer damage to flowers, pods and seeds were estimated and presented in Table 3.

There was no correlation between flower damage assessed on the basis of larval population in flowers (number of larvae per 25 flowers) and seed damage index. The two criteria for pod damage assessment viz., percentage pod infestation and pod

Table 3 Correlations among various parameters of pod borer damage

Damage parameters	Per cent pod infestation	Seed damage index	Pod damage severity
No. of larvae per 25 flowers	-0.0807	0.0006	-0.1662
Per cent pod infestation		0.5422**	0.7729**
Seed damage index			0.6247**

** Significant at 1 per cent level

damage severity showed highly significant positive correlation between them (r = 0.7729) but both these were found to be uncorrelated with larval count in flowers. Pod damage severity as well as percentage pod infestation was positively and significantly correlated with seed damage index.

4.1.3 Leaf chlorophyll content and legume pod borer resistance

The mean chlorophyll content in leaf of the 51 cultivars are given in Table 4. There were significant differences among cultivars in total leaf chlorophyll content.

Total chlorophyll content of leaf tissue ranged from 0.710 mg g^{-1} (Vs 15) to 1.692 mg g^{-1} (Vs 43). Of the 51 cultivars evaluated, 19 of them were on par with Vs 15 while nine others were found to be on par with Vs 43.

The results of the correlation analysis made to determine the role of leaf chlorophyll content in legume pod borer resistance are presented in Table 5. The analysis provided non-significant 'r' values thereby indicating the absence of any relationship between the overall plant resistance indices (Ipr) and total chlorophyll content in leaf tissues. Further it was found that there was no correlation between leaf chlorophyll contents and pod damage assessed as percentage pod infestation or pod damage severity.

4.1.4 Non-glandular trichome density on pods, pod width and peduncle length and their effect on legume pod borer resistance

Pod width, non-glandular trichome density on pods and peduncle length were found to exhibit significant differences among the cultivars (Table 6).

Table 4 Mean chlorophyll content in leaves of 51 accessions (mg g^{-1} of tissue)

Acc. No.	Total Chlorophyll	Acc. No.	Total Chlorophyll
Vs 1	1.098	Vs 27	1.037
Vs 2	1.340	Vs 28	1.133
Vs 3	0.877	Vs 29	1.068
Vs 4	1.290	Vs 30	1.072
Vs 5	0.812	Vs 31	1.053
Vs 6	1.314	Vs 32	1.272
Vs 7	1.461	Vs 33	1.078
Vs 8	1.678	Vs 34	1.435
Vs 9	1.451	Vs 35	1.300
Vs 10	1.015	Vs 36	1.188
Vs 11	0.998	Vs 37	1.173
Vs 12	0.796	Vs 38	1.259
Vs 13	0.819	Vs 39	1.219
Vs 14	0.967	Vs 40	1.153
Vs 15	0.710	Vs 41	1.491
Vs 16	1.250	Vs 42	1.058
Vs 17	1.128	Vs 43	1.692
Vs 18	1.038	Vs 44	1.138
Vs 19	1.461	Vs 45	1.022
Vs 20	0.951	Vs 46	1.058
Vs 21	1.362	Vs 47	1.249
Vs 22	1.274	Vs 48	1.249
Vs 23	0.908	Vs 49	1.511
Vs 24	0.873	Vs 50	1.148
Vs 25	1.042	Vs 51	1.159
Vs 26	0.867		

$F_{50,50}$ = 3.08** $CD_{0.05}$ = 0.3595 CV = 15.42 %

** Significant at 1 per cent level

Table 5 Correlation of Ipr, pod damage severity and percentage pod infestation with total leaf chlorophyll content in vegetable cowpea

Parameters	Total leaf chlorophyll
Ipr	-0.0415
Pod damage severity	-0.0189
Percentage pod infestation	-0.0384

Table 6 Pod width, non-glandular trichome density on pods (number mm^{-2}) and peduncle length of the 51 vegetable cowpea cultivars

Acc. No.	Pod width (mm)	Trichome density	Peduncle length (cm)
Vs 1	6.58	3.0	14.21
Vs 2	7.58	5.0	17.00
Vs 3	7.67	6.0	12.98
Vs 4	7.83	4.0	11.11
Vs 5	7.42	5.0	13.24
Vs 6	8.33	3.5	17.12
Vs 7	9.08	4.5	13.84
Vs 8	8.75	3.5	16.64
Vs 9	8.50	6.0	12.76
Vs 10	8.08	7.0	18.74
Vs 11	6.58	4.5	15.44
Vs 12	8.58	3.5	13.03
Vs 13	8.00	6.5	15.04
Vs 14	7.75	5.0	14.59
Vs 15	8.00	3.0	11.91
Vs 16	7.75	3.5	11.52
Vs 17	8.00	2.5	13.37
Vs 18	9.67	2.5	14.13
Vs 19	7.17	4.5	19.04
Vs 20	8.83	2.5	18.86
Vs 21	6.58	6.5	17.36
Vs 22	7.83	5.5	11.71
Vs 23	8.23	2.5	11.96
Vs 24	6.00	4.5	12.86
Vs 25	6.42	5.5	12.34
Vs 26	5.42	2.5	12.07
Vs 27	4.42	2.0	13.36
Vs 28	5.33	3.5	10.64

Acc. No.	Pod width (mm)	Trichome density	Peduncle length (cm)
Vs 29	5.33	2.0	15.49
Vs 30	5.67	3.0	15.62
Vs 31	6.17	2.0	18.11
Vs 32	6.17	3.5	13.30
Vs 33	5.83	3.5	16.41
Vs 34	7.00	3.5	12.94
Vs 35	6.83	2.5	14.11
Vs 36	5.75	3.0	14.00
Vs 37	7.17	3.0	11.21
Vs 38	7.25	2.0	13.82
Vs 39	6.25	2.5	10.49
Vs 40	5.25	2.5	13.57
Vs 41	7.83	2.0	10.99
Vs 42	8.17	3.0	18.27
Vs 43	11.0	4.0	17.93
Vs 44	7.75	1.5	15.06
Vs 45	6.58	2.5	13.49
Vs 46	7.83	1.5	21.57
Vs 47	7.83	2.0	14.64
Vs 48	8.17	2.0	14.40
Vs 49	7.58	2.5	15.87
Vs 50	8.00	4.0	14.97
Vs 51	7.25	2.0	16.44
$F_{50,50}$	28.24**	2.60**	7.81**
$CD_{0.05}$	0.667	2.487	2.547
CV(%)	4.54	35.46	8.74

** Significant at 1 per cent level

The measure of width of pods at vegetable harvest stage ranged from 4.42 mm in Vs 27 to 11.50 mm in Vs 43. However no other variety was found to be statistically on par with either of them.

Non-glandular trichome number mm^{-2} area of pod wall surface ranged from 1.5 (Vs 44 and Vs 46) to 7.00 (Vs 10). Thirty two other cultivars were statistically on par with the varieties with lowest count mentioned above i.e., Vs 44 and Vs 46. But Vs 10 was statistically on par with nine other cultivars (Vs 2, Vs, Vs 3, Vs 5, Vs 9, Vs 13, Vs 14, Vs 21, Vs 22 and Vs 25). Plate 10 shows the non-glandular trichomes on pods.

Peduncle length varied from 10.49 cm (Vs 39) to 21.57 cm (Vs 46). Vs 19 was the only variety on par with Vs 46. Fifteen other varieties had short peduncles, their length being not significantly different from that of Vs 39.

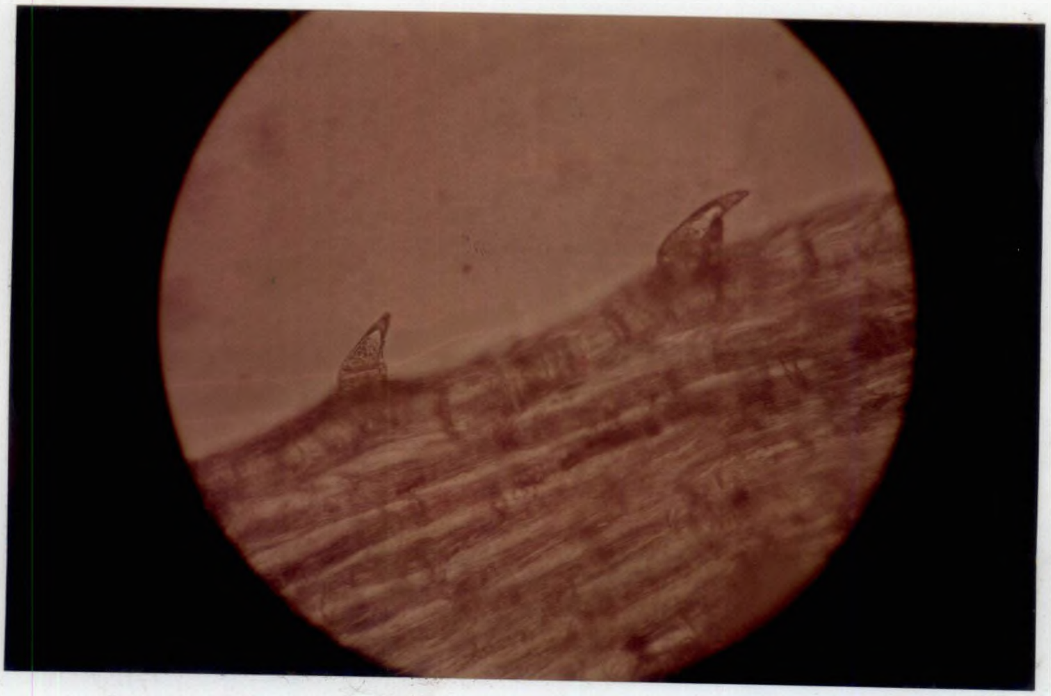
The correlation coefficients of damage parameters (Ipr, pod damage severity and percentage pod infestation) with the three above mentioned characters i.e., pod width, non-glandular trichome density and peduncle length are presented in Table 7. Pod width was found to be positively correlated with Ipr (r = 0.2684), pod damage severity (r = 0.4067) and percentage pod infestation (0.3290). Non glandular trichome density on pod was found to be negatively correlated with Ipr and pod damage severity. This suggested that the overall plant resistance increases with increase in non-glandular trichome density on pods. However correlation between non-glandular trichome density and percentage pod infestation was not significant. Damage parameters were not at all influenced by peduncle length.

Tbale 7 Correlation coefficients of Ipr and pod damage parameters with pod characters

	Pod width	Non-glandular trichome density on pods	Peduncle length
Ipr	0.2684**	-0.2009*	-0.0740
Pod dmage severity	0.4067**	-0.2474*	-0.0442
Percentage pod infestation	0.3290**	-0.1451	-0.1734

** Significant at 1 per cent level
* Significant at 5 per cent level

Plate 10 : Non-glandular trichomes on pod wall surface



4.2 Yield evaluation of selected partially resistant cultivars

The data collected on vegetable pod yield and other morphological characters from the field experiment with 15 partially resistant cultivars were statistically analysed and the results obtained are presented below.

4.2.1 Mean performance of varieties

The analysis of variance (Table 8) revealed significant differences among the varieties for all the characters studied except length of main stem, number of primary branches and number of seeds per pod. The mean performance of each of the 15 cultivars for the 14 characters under study are furnished in Table 9.

Among the varieties, Vs 13 was the one that took minimum number of days to flowering (37.67) as well as first picking (48.27) while Vs 19 took maximum number of days for first flowering (47.87) and first picking (57.40). Varieties Vs 24, Vs 29, Vs 7, Vs 14, Vs 10, Vs 8 and Vs 2 were not significantly different from Vs 13 with respect to days taken for first flowering. Apart from these varieties, Vs 31, Vs 28 and Vs 27 were found to be statistically on par with Vs 13 for the number of days to first picking. Length of harvesting period was maximum for Vs 13 (43.53 days) and minimum for Vs 19 (34.53 days). Vs 29, Vs 24 and Vs 14 were the other varieties with longer harvesting period.

There were no significant differences among the varieties with respect to length of mainstem and number of primary branches. Peduncle length was maximum for Vs 19 (19.1 cm) and minimum for Vs 28 (9.8 cm).

The maximum number of inflorescences per plant was given by Vs 19

Table 8. Analysis of variance of 14 characters in 15 vegetable cowpea genotypes

Sl. No.	Characters	Mean squares		
		Replication	Genotype	Error
	df	2	14	28
1.	Days to first flowering	6.42	23.33**	5.72
2.	Days to first harvest	10.70	17.60**	4.81
3.	Length of harvesting period	13.34	17.88**	5.02
4.	Length of main stem (cm)	7336.50	1221.21	2351.39
5.	Number of primary branches	0.58	0.58	0.66
6.	Length of peduncle (cm)	3.59*	17.8**	1.02
7.	Number of inflorescences per plant	105.38**	49.41**	9.64
8.	Number of pods per inflorescence	0.30	0.62**	0.15
9.	Number of pods per plant	35.78	1627.71**	21.63
10.	Yield of vegetable pods per plant (g)	6284	306589.7**	5157.71
11.	Pod length (cm)	4.16	51.09**	4.64
12.	Pod girth (mm)	3.16	17.02**	2.86
13.	Pod weight (g)	6.38	19.95**	1.55
14.	Number of seeds per pod	2.89	3.93	2.72

** Significant at 1 per cent level

* Significan at 5 per cent level

Table 9 Plant, pod characters and yield of 15 vegetable cowpea genotypes

Acc. No.	Days to 1st flowering	Days to 1st harvest	Length of harvesting period	Length of main stem (cm)	No. of primary branches	Length of peduncle (cm)	No. of inflorescences per plant	No. of pods per inflorescence	No. of pods per plant	yield of vegetable pods per plant (g)	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds per pod
Vs 2	41.33	49.73	41.87	448.73	3.07	17.50	23.60	2.37	54.13	1096.33	40.50	31.90	21.03	14.50
Vs 7	39.87	50.53	41.53	475.33	3.53	14.13	24.87	3.17	99.40	1266.73	38.37	24.10	12.67	16.87
Vs 8	41.27	50.87	41.07	414.33	2.93	15.97	22.47	2.77	135.60	1654.80	40.63	23.87	12.00	19.33
Vs 10	41.13	50.87	41.33	428.87	3.20	18.80	29.93	2.63	94.27	1075.27	41.17	26.40	11.60	16.27
Vs 13	37.67	48.27	43.53	408.73	3.53	14.87	20.07	1.73	92.13	1419.00	44.47	25.67	15.50	17.97
Vs 14	41.00	49.73	42.07	465.73	3.13	14.73	20.80	3.27	117.00	1797.73	40.10	25.67	15.73	17.37
Vs 19	47.87	57.40	34.53	470.53	2.60	19.10	34.67	2.60	69.40	969.27	44.57	23.80	14.03	17.40
Vs 21	44.73	53.87	38.20	464.67	3.73	17.00	22.80	3.23	92.53	1659.40	38.33	27.13	16.70	18.50
Vs 24	39.53	49.47	42.60	443.60	3.67	13.13	25.67	3.07	104.87	1704.40	44.43	26.80	16.10	16.87
Vs 27	42.73	51.87	40.13	452.47	4.07	13.80	28.07	2.47	75.13	925.60	31.00	24.33	12.67	17.30
Vs 28	42.67	51.73	40.07	449.20	3.20	9.80	20.87	3.40	57.20	1025.53	49.20	30.47	18.63	16.13
Vs 29	39.53	49.07	42.67	432.40	3.47	15.53	24.93	2.37	99.33	1426.00	38.73	24.47	14.30	17.60
Vs 31	43.40	51.60	40.13	446.67	3.27	18.43	20.53	3.13	70.60	1103.27	40.73	27.27	15.70	17.53
Vs 35	46.93	54.87	36.73	442.07	2.33	14.87	24.80	2.70	56.87	711.27	39.50	25.60	12.70	15.87
Vs 40	43.47	52.80	38.60	421.73	3.27	15.70	28.33	2.43	88.93	1319.20	44.47	24.37	15.03	17.00
$CD_{0.05}$	4.00	3.67	3.75	-	-	1.69	5.19	0.65	7.77	120.09	3.60	2.83	2.08	-
SE	± 1.38	± 1.27	± 1.29	± 27.99	± 0.47	± 0.58	± 1.79	± 0.23	± 2.69	± 41.46	± 1.24	± 0.98	± 0.72	± 0.95

(34.67). The only other variety statistically on par with Vs 19 was Vs 10. Least number of inflorescences per plant was recorded by Vs 13. Regarding the number of pods per inflorescence, the highest and lowest values of 3.40 and 1.73 were recorded by Vs 28 and Vs 13 respectively. Vs 14, Vs 21, Vs 7, Vs 31, Vs 24 and Vs 8 had higher number of pods per inflorescence and expressed statistical parity for the character with Vs 28. The variety Vs 8 gave the highest number of pods (135.60) per plant, followed by Vs 14 (117.00), Vs 24 (104.87), Vs 7 (99.40), Vs 29 (99.33) and Vs 10 (94.27). The minimum number of pods per plant was recorded by Vs 2 (54.13).

Yield of vegetable pods per plant was maximum for Vs 14 (1797.73 g) and minimum for Vs 35 (711.27 g). Vs 24 (1704.4 g) was the only variety on par with Vs 14.

The pod characters viz., pod length, pod girth and pod weight differed significantly among varieties. However significant statistical difference among varieties was not evident for number of seeds per pod.

Pod length was maximum for Vs 28 (49.2 cm) which was significantly high in comparison with all other varieties. Vs 19 (44.57), Vs 40 (44.47), Vs 13 (44.47), Vs 24 (44.43) and Vs 10 (41.17) were on par. Least pod length was recorded by Vs 27 (31 cm). Pod girth was maximum for Vs 2 (31.9 mm) and minimum for Vs 19 (23.8 mm). Vs 28 (30.47) was on par with Vs 2. Significantly higher pod weight in comparison to other varieties was recorded by Vs 2 (21.03 g). Pod weight was minimum for Vs 10 (11.6 g).

4.2.2 Variability studies

The phenotypic variance, genotypic variance and coefficient of variation for the 14 characters are presented in Table 10 and Fig 1. The maximum value for GCV was observed for number of pods per plant (26.55) followed by yield of vegetable pods per plant (24.94), pod weight (16.52), length of peduncle (15.21), number of inflorescences per plant (14.67) and number of pods per inflorescence (14.31).

The highest PCV was observed for number of pods per plant (27.08) followed by yield of vegetable pods per plant (25.57), number of primary branches (24.37), number of pods per inflorescence (20.16), number of inflorescences per plant (19.27) and pod weight (18.53). Least PCV was recorded for days to first harvest (5.85).

The difference between genotypic and phenotypic coefficients of variation was least for number of pods per plant (0.53 per cent) and was maximum for number of seeds per pod followed by number of pods per inflorescence and number of inflorescences per plant.

4.2.3 Heritability and genetic advance

The estimates of heritability and genetic advance are presented in table 11 and the corresponding graphical representation in Fig.2. High values of heritability were recorded by number of pods per plant (96.12 per cent) followed by yield of vegetable pods per plant (95.12 per cent), length of peduncle (84.53 per cent), pod weight (79.83 per cent), pod length (76.95 per cent) and

Table 10 Components of variance for 14 traits in vegetable cowpea

Sl. No.	Characters	Mean ± SE	σ^2g	σ^2e	σ^2p	GCV %	PCV %
1.	Days to first flowering	42.21 ± 1.38	5.869	5.728	11.597	5.74	8.07
2.	Days to first harvest	51.51 ± 1.27	4.260	4.818	9.078	4.01	5.85
3.	Length of harvesting period	40.33 ± 1.29	4.287	5.024	9.311	5.13	7.56
4.	Number of pods per plant	87.16 ± 2.69	535.360	21.631	556.990	26.55	27.08
5.	Yield of vegetable pods per plant (g)	1270.92 ±41.46	100477.100	5158.00	105635.100	24.94	25.57
6.	Numberof inflorescences per plant	24.82 ± 1.79	13.256	9.643	22.899	14.67	19.27
7.	Number of pods per inflorescence	2.76 ± 0.23	0.155	0.153	0.309	14.31	20.16
8.	Length of peduncle (cm)	15.56 ± 0.58	5.598	1.024	6.622	15.21	16.54
9.	Length of main stem (cm)	444.33 ± 28	n.e.	2351.393	1974.667	n.e.	10.00
10.	Number of primary branches	3.27 ± 0.47	n.e.	0.664	0.635	n.e.	24.37
11.	Pod length (cm)	41.08 ± 1.24	15.484	4.638	20.122	9.58	10.92
12.	Pod girth (mm)	26.12 ± 0.98	4.720	2.856	7.576	8.32	10.54
13.	Pod weight (g)	14.96 ± 0.72	6.135	1.550	7.685	16.52	18.53
14.	Number of seeds per pod	17.09 ± 0.95	0.405	2.719	3.125	3.72	10.33

σ^2g - genotypic variance
σ^2e - environmental variance
σ^2p - phenotypic variance
PCV - phenotypic coefficient of variation
GCV - Genotypic coefficient of variation
n.e. - not estimable

Table 11 Heritability, genetic advance and genetic gain for 12 traits in vegetable cowpea

Sl. No.	Characters	Heritability (%)	Genetic advance (at 5 per cent selection)	Genetic gain (as percentage of mean)
1.	Days to first flowering	50.61	3.55	8.41
2.	Days to first harvest	46.93	2.91	5.65
3.	Length of harvesting period	46.04	2.89	7.17
4.	Number of pods per plant	96.12	46.73	53.61
5.	Yield of vegetable pods per plant (g)	95.12	636.84	50.11
6.	Number of inflorescences per plant	51.88	5.71	23.00
7.	Number of pods per inflorescence	50.35	0.58	21.01
8.	Length of peduncle (cm)	84.53	4.48	28.79
9.	Pod length (cm)	76.95	7.11	17.30
10.	Pod girth (mm)	62.30	3.53	13.51
11.	Pod weight (g)	79.83	4.56	30.48
12.	Number of seeds per pod	12.97	0.47	2.75

pod girth (62.30). The characters viz., number of inflorescences per plant (51.88 per cent), days to first flowering (50.6 per cent), number of pods per inflorescence (50.35 per cent), days to first harvest (46.93 per cent), length of harvesting period (46.04 per cent) recorded medium heritability. Low heritability was recorded by number of seeds per pod (12.97 per cent).

Expected genetic gain as percentage of mean was high for number of pods per plant (53.61 per cent) followed by yield of vegetable pods per plant (50.11 per cent), pod weight (30.48 per cent), length of peduncle (28.79 per cent) and number of inflorescences per plant (23.00 per cent). Days to first flowering, days to first harvest, length of harvesting period, pod length, pod girth and number of seeds per pod exhibited low genetic advance. Number of seeds per pod recorded the least genetic advance (2.75 per cent). High values of heritability estimates coupled with high genetic advance were recorded for number of pods per plant, yield of vegetable pods per plant, pod weight and length of peduncle.

4.2.4 Correlation analysis

The genotypic, phenotypic and environmental covariances and their corresponding correlation coefficients were estimated for all the possible pairs of characters. The results on the correlation analysis are presented under the following subtitles.

(a) Correlation between yield and other characters

(b) Correlation among the yield component characters

(a) Correlation between yield and other characters

The genotypic, phenotypic and environmental correlations between yield and its components are presented in Table 12.

The phenotypic correlation was found to be highly significant and positive for the characters, number of pods per plant (0.8398) followed by length of harvesting period (0.3919) and number of seeds per pod (0.3453). Days to first flowering (-0.4326), days to first harvest (-0.3830) and number of inflorescences per plant (-0.3422) recorded significant negative correlation with pod yield.

The genotypic correlation of yield with all other characters except days to first flowering, days to first harvest, number of inflorescences per plant and pod girth were found to be positive. Number of seeds per pod had the highest positive correlation with pod yield per plant (1.0103) followed by number of pods per plant (0.835), length of harvesting period (0.6436) and number of pods per inflorescence (0.2203).

At environmental level number of pods per plant (0.9502) had the highest positive correlation with yield followed by days to first harvest (0.2177), length of main stem (0.1416) and days to first flowering (0.1240). Length of harvesting period, number of inflorescences per plant, number of pods per inflorescence, pod girth and number of seeds per pod recorded negative correlation with pod yield.

Table 12 Genotypic, phenotypic and environmental correlation coefficients between vegetable pod yield per plant and other characters

Sl. No.	Characters	Correlation coefficients		
		Genotypic	Phenotypic	Environmental
1.	Days to first flowering	-0.6513	-0.4326**	0.1240
2.	Days to first harvest	-0.6257	-0.3830**	0.2177
3.	Length of harvesting period	0.6436	0.3919**	-0.2093
4.	Number of pods per plant	0.8350	0.8398**	0.9502
5.	Number of inflorescences per plant	-0.4149	-0.3422*	-0.2394
6.	Number of pods per inflorescence	0.2203	0.1344	-0.1155
7.	Length of main stem	n.e.	-0.0346	0.1416
8.	Number of primary branches	n.e.	0.1942	0.0158
9.	Pod length	0.0977	0.0859	0.0226
10.	Pod girth	-0.1662	-0.1325	-0.0336
11.	Pod weight	0.1051	0.0982	0.0664
12.	Number of seeds per pod	1.0103	0.3453*	-0.0462

** Significant at 1 per cent * Significant at 5 per cent level n.e. Not estimable

(b) Correlation among the yield component characters

The genotypic, phenotypic and environmental correlation coefficients among the yield components were computed and are presented in Table 13, 14 and 15.

1) Days to first flowering

Number of days to first flowering showed positive phenotypic correlation with days to first harvest (0.9506) as well as number of inflorescences per plant (0.3778). Significant negative correlation was obtained with the length of harvesting period (-0.9525) followed by number of pods per plant (-0.4013). High genotypic correlation was observed with days to first harvest, inflorescences per plant and pods per inflorescence. Its association with days to first harvest (0.9784) was the highest and it showed highest negative correlation with length of harvesting period (-0.9939). High positive environmental correlation was observed with days to first harvest (0.9255) and high negative correlation with length of harvesting period (-0.9158).

2) Days to first harvest

At phenotypic level, significant positive correlation was observed with days to first flowering (0.9506) and inflorescences per plant (0.4520) while length of harvesting period (-0.9915) and number of pods per plant (-0.3122) exhibited significant negative correlation. This character exhibited positive genotypic correlation with days to first flowering (0.9784) followed by number of inflorescences per plant (0.6854), number of pods per inflorescence (0.2674) and pod length (0.0852). Length of harvesting period exhibited

Table 13 Phenotypic correlation coefficients among the yield component characters

Characters	Days to first harvest	Length of harvesting period	No. of pods per plant	No. of inflorescences per plant	No. of pods per inflorescence	Length of main stem	No. of primary branches	Pod length	Pod girth	Pod weight	No. of seeds per pod
1. Days to first flowering	0.9506**	-0.9525**	-0.4013**	0.3778**	0.0858	0.2302	-0.2659	-0.0534	-0.0512	-0.0621	0.0304
2. Days to first harvest		-0.9915**	-0.3122*	0.4520**	0.0941	0.2394	-0.1908	-0.0252	-0.1641	-0.1423	0.0730
3. Length of harvesting period			0.334*	-0.4294**	-0.0744	-0.2113	0.2152	0.0116	0.1437	0.1012	-0.0912
4. No. of pods per plant				-0.1431	0.0600	-0.1018	0.1322	-0.0966	-0.4624**	-0.3813**	0.4484**
5. No. of inflorescences per plant					-0.1102	0.1493	0.1113	-0.1729	-0.3806**	-0.3391**	-0.1210
6. No. of pods per inflorescence						0.0745	0.1010	0.0911	0.2224	0.1011	0.1204
7. Length of main stem							-0.0205	-0.1728	0.0146	0.0139	-0.0266
8. No. of primary branches								-0.2409	-0.1105	-0.0289	-0.1061
9. Pod length									0.2780	0.3719*	-0.0280
10. Pod girth										0.7259**	-0.2154
11. Pod weight											-0.1042

** Significant at 1 per cent level   * Significant at 5 per cent level

Table 14 Genotypic correlation coefficients among the yield component characters

Characters	Days to first harvest	Length of harvesting period	No. of pods per plant	No. of inflorescences per plant	No. of pods per inflorescence	Length of main stem	No. of primary branches	Pod length	Pod girth	Pod weight	No. of seeds per pod
1. Days to first flowering	0.9784	-0.9939	-0.5900	0.5169	0.3619	ne	ne	0.0192	-0.0789	-0.0992	-0.3304
2. Days to first harvest		-1.0010	-0.5032	0.6854	0.2674	ne	ne	0.0852	-0.2532	-0.2423	-0.0982
3. Length of harvesting period			0.5413	-0.6640	-0.2316	ne	ne	-0.1116	0.2395	0.2120	0.2213
4. No. of pods per plant				-0.1489	0.1077	ne	ne	-0.1272	-0.5860	-0.4523	1.2435
5. No. of inflorescences per plant					-0.3359	ne	ne	-0.0129	-0.4280	-0.4634	-0.2079
6. No. of pods per inflorescence						ne	ne	0.0818	0.1941	0.1304	0.1369
7. Length of main stem							0.2302	ne	ne	ne	ne
8. No. of primary branches								ne	ne	ne	ne
9. Pod length									0.3651	0.4077	-0.3584
10. Pod girth										0.9311	-1.4683
11. Pod weight											-1.0434

ne : not estimable

Table 15 Environmental correlation coefficients among the yield component characters

Characters	Days to first harvest	Length of harvesting period	No. of pods per plant	No. of inflorescences per plant	No. of pods per inflorescence	Length of main stem	No. of primary branches	Pod length	Pod girth	Pod weight	No. of seeds per pod
1. Days to first flowering	0.9255**	-0.9158**	0.0732	0.2149	-0.1956	0.1659	-0.0422	-0.1936	-0.0160	0.0031	0.1755
2. Days to first harvest		-0.9834**	0.1796	0.2005	-0.0699	0.181	0.0513	-0.2186	-0.0607	0.0182	-0.1431
3. Length of harvesting period			-0.1844	-0.1817	0.0716	-0.1477	-0.027	0.2211	0.0342	-0.0828	-0.2119
4. No. of pods per plant				-0.2505	-0.1073	0.0667	-0.0088	0.1357	-0.0738	0.1679	0.0509
5. Number of inflorescences per plant					0.1557	0.1715	0.4337**	-0.5273**	-0.3101*	-0.0827	-0.1058
6. No. of pods per inflorescence						-0.3009*	0.2096	0.1187	0.2628	0.0583	0.2363
7. Length of main stem							-0.376	-0.2165	-0.0479	-0.1639	0.0472
8. No. of primary branches								-0.1684	-0.2409	-0.222	-0.3103
9. Pod length									0.0857	0.2428	0.1903
10. Pod girth										0.2512	0.3526*
11. Pod weight											0.5526

** Significant at 1 per cent level   * Significant at 5 per cent level significant negative correlation (-0.9834) at environmental level while days to first flowering recorded significant positive correlation (0.9255).

3) Length of harvesting period

Number of pods per plant alone showed significant positive correlation at phenotypic level, while days to first flowering, days to first harvest and number of inflorescences per plant recorded significant negative correlations with this character. This trait exhibited positive genotypic correlation with the characters number of pods per plant (0.5413), pod girth (0.2395), pod weight (0.2120)and number of seeds per pod (0.2213). Highest negative correlation was recorded with days to first harvest (-1.0010) followed by days to first flowering (-0.9939). Days to first flowering and days to first harvest showed significant negative correlation at environmental level.

4) Number of pods per plant

At phenotypic level significant positive correlation was observed with length of harvesting period and number of seeds per pod and significant negative correlation with pod girth, pod weight, days to first flowering and days to first harvest. The characters number of seeds per pod, length of harvesting period and number of pods per inflorescence recorded positive correlation with this character at genotypic level. Number of seeds per pod recorded maximum positive correlation (1.2435) while days to first flowering (-0.59) recorded maximum negative correlation. Environmental correlations were not significant.

5) Number of inflorescencesper plant

Significant positive phenotypic correlation was observed between this character and the characters namely days to first flowering and days to first harvest while significant negative correlations were observed with length of harvesting period, pod girth and pod weight. Number of inflorescences per plant showed positive correlation with days to first flowering and days to first harvest at genotypic level. Its association with days to first harvest was the highest (0.6854) and it showed highest negative correlation with length of harvesting period (-0.6640). At environmental level significant positive correlation was obtained with number of primary branches and significant negative correlation with pod length and pod girth.

6) Number of pods per inflorescence

Phenotypic correlations of number of pods per inflorescence with other characters were not significant. Days to first flowering recorded maximum positive genotypic correlation (0.3619) while number of inflorescences per plant recorded maximum negative genotypic correlation (-0.3559). At environmental level length of main stem recorded significant negative correlation (-0.3009) with pods per inflorescence.

7) Length of main stem

Phenotypic correlations with other characters were not significant Number of primary branches alone showed positive genotypic correlation

(0.2302) with this character. Pods per inflorescence exhibited significant negative correlation at environmental level (-0.3009). Most of the correlations were not estimable indicating the high influence of environment on this character.

8) Number of primary branches

None of the characters showed significant phenotypic correlation with this character. Length of main stem alone showed positive correlation (0.2302) with number of primary branches at genotypic level. Number of inflorescences per plant recorded significant positive correlation (0.4337), at environmental level. This characters was highly influenced by environmental conditions.

9) Pod length

Pod weight recorded significant phenotypic correlation (0.3719) with this characters. This character showed positive genotypic correlation with pod girth and pod weight. Highest positive genotypic correlation was with pod weight (0.4077) and highest negative correlation (-0.3584) with seeds per pod. At environmental level number of inflorescences per plant alone recorded significant negative correlations (-0.5273).

10) Pod girth

Pod girth recorded significant positive correlation with pod weight and significant negative phenotypic correlation with number of pods per plant and number of inflorescences per plant. This trait had maximum positive genotypic correlation with pod weight followed by pod length, length of harvesting period and number of pods per inflorescence. Environment correlation was negatively significant for number of inflorescences per plant and positive for number of seeds per pod.

11) Pod weight

Phenotypic correlation was positive and significant with pod length and pod girth. Negative correlation was obtained for number of pods per plant and number of inflorescences per plant. At genotypic level, maximum positive correlation was observed with pod girth (0.9311) followed by pod length (0.4077), length of harvesting period (0.2120) and number of pods per inflorescence (0.1304). Maximum negative correlation was with the character seeds per pod. Environmental correlations were not significant.

12) Seeds per pod

Phenotypic correlation was positive and significant for the character number of pods per plant. This character showed maximum positive correlation with number of pods per plant and maximum negative correlation with pod girth at the genotypic level. Pod girth recorded significant positive correlation at environmental level.

4.2.5 Path analysis

Correlation studies help in designing appropriate selection strategies while path coefficient analysis reveals the cause of association and pinpoints

Table 16 Direct and indirect effects of various component characters on the yield of vegetable cowpea

Characters	Days to first flowering	Days to first harvest	Length of harvesting period	Number of pods per plant	Number of inflorescences per plant	Total correlation
1. Days to first flowering	0.9228	-1.1004	0.0147	-0.4839	-0.0045	-0.6513
2. Days to first harvest	0.9028	-1.1247	0.0149	-0.4127	-0.0060	-0.6257
3. Length of harvesting period	-0.9171	1.1258	-0.0148	0.4440	0.0058	0.6436
4. No. of pods per plant	-0.5444	0.5659	-0.0080	0.8202	0.0013	0.8350
5. No. of inflorescences per plant	0.4770	-0.7708	0.0099	-0.1221	-0.0088	-0.4149

Residual effect R = 0.2183
Underlined figures are direct effects

the actual parameters to be manipulated. The characters viz., days to first flowering, days to first harvest, length of harvesting period, number of pods per plant and number of inflorescence per plant are presented in Table 16 and Fig. 3.

A perusal of the table revealed that maximum direct effect on yield was contributed by days to first flowering (0.9228) followed by number of pods per plant (0.8202). Direct effect of days to first harvest, length of harvesting period and number of inflorescences per plant were negative.

For the character days to first flowering total correlation was negative (-0.6513) while the direct effect was high and positive (0.9228). The negative correlation between days to first flowering and yield may be due to the high indirect effect of this character through other components such as days to first harvest (-1.1004) and number of pods per plant (-0.4839). Length of harvesting period and number of inflorescences per plant have not contributed towards yield.

Direct effect of days to first harvest was negative and high and its correlation with yield was also the same. The high positive indirect effect via days to first flowering nullfied the direct effect of days to first harvest.

Direct effect of length of harvesting period was low and negative (-0.0148) while total correlation was positive and high (0.6436). So this high positive correlation between length of harvesting period and yield might have resulted through the positive indirect effect via days to first harvest (1.1258) and number of pods per plant (0.4440) on yield.

Number of pods per plant had high direct effect (0.8202) as well as high positive correlations (0.8350) with yield. So this correlation explained true relationship of number of pods per plant and yield. Hence number of pods per plant can be taken as a reliable character for selection.

Number of inflorecensces per plant recorded negative correlation and its direct effect was negligible. The high positive indirect effect via days to first flowering (0.4770) and negative indirect effect via days to first harvest (-0.7708) resulted in this correlation.

Days to first flowering, days to first harvest and number of pods per plant are the main characters which influence the yield directly and indirectly. Hence these characters can be considered during selection programmes for identifying high yielding vegetable cowpea genotypes. The residue obtained (0.2183) indicated that 78.17 per cent of the variation could be explained by the path coefficient model.

5. DISCUSSION

The discussion that follows is based on the results of the two field experiments conducted with the objectives of screening vegetable cowpea germplasm for legume pod borer resistance and evaluation of yield performance of selected partially resistant cultivars. The topic is treated under different headings.

5.1 Screening for legume pod borer resistance

Search for sources of resistance to insect pests should ideally start from within the species since utilization of such sources in conventional breeding programmes is quite easy and straightforward. Resistance being often found in traditional varieties (Saxena and Khan, 1991), screening local cultivars is the foremost step. Accordingly the material for the present investigation comprised primarily of unimproved traditional cultivars of vegetable cowpea collected from different localities (Table 1).

Hostplant resistance of a genotype to an insect pest is assessed as its reaction to the pest in comparison with other genotypes of the species. Hence, host plant resistance of a variety is definable only in terms of other varieties with differential reaction to the pest. For field screening to be effective and reliable, it is imperative that the screening should be done under uniform and reasonably high insect population pressure. However, natural infestation often fails to develop at desired time or magnitude in field screening programmes.

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But artificial infestation and other measures that ensure building up of pest population in screening fields can be successfully employed. Placement of egg masses or larvae of the target pest on the test plants is widely employed in insect resistance screening programmes (Pathak *et al.*, 1971; Chatterji *et al.*, 1971; Guthrie and Carter, 1972 and Dabrowski *et al.*, 1983). Planting a susceptible cultivar of the crop in question along the borders of the experimental field with the view of the pest population build up in the experimental field is also a usually adopted practice (Jackai, 1982; Oghiakhe *et al.*, 1993). The measures adopted in this programme to achieve this end included the release of second instar larvae of *M. vitrata* to the experimental plots at the early flowering phase of the crop and planting a susceptible local grain cowpea cultivar along the borders of the experimental field. The data on flower and pod damages in table 2 indicated that adequate pest population could be developed in the experimental field. Moreover application of Monocrotophos at lower dose adopted as a standard practice for selective elimination of non-target pests in the *M. vitsata* resistance studies (Jackai and Singh, 1988; Oghiakhe *et al.*, 1992 a) was also employed in the present programme.

5.1.1 Variation in damage parameters and overall plant resistance indices

A variety that suffers lesser insect attack or lesser damage in the event of comparable pest population can be considered as partially resistant (Dent, 1995). Tingey (1986) suggested that assessment of plant resistance through measurements of insect damage should be made employing damage criteria closely associated with ultimate loss in crop yield and quality. The field screening technique involving computation of overall plant resistance index (Ipr) based on flower, pod and seed damage parameters (Jackai, 1982) was employed in the present study.

Significant differences among cultivars were observed for all the parameters employed for damage assessment, viz., number of larvae per 25 flowers, percentage pod infestation, pod damage severity and seed damage index (Table 2). Highest degree of flower infestation was observed for Vs 33 and was nearly four times as that of the least affected cultivar, Vs 27. Similarly Jackai (1982) reported wide differences in larval population in flowers of cowpea varieties in a legume pod borer screening programme. In this context it is also worth mentioning that significantly higher legume pod borer larval counts in flowers of susceptible compared to resistant cultivars were reported in studies by Oghiakhe *et al.* (1992 b). Jackai (1982) opined that larval count in flowers is very important as the information thus obtained provides an insight on the pest population intensity in each cultivar since larvae tend to migrate from one flower to the other.

In assessment of damage to pods, both the methods employed i.e., percentage pod infestation and pod damage severity suggested Vs 28 and Vs 2 as the cultivars with least pod damage. Cultivars Vs 30 and Vs 19 with similar low pod damage severity were found to have low percentage pod infestation as well. Apart from these, eight other cultivars also registered low level of percentage pod infestation. Vs 46 and Vs 18 registered significantly higher pod damage severity than other cultivars. Vs 51 along with six other cultivars were found to suffer heavy pod damage in terms of percentage pod infestation.

Seed damage index values ranged from 15 to 330. Vs 13 showed the lowest seed damage. Low level of seed damage was expressed by nine other cultivars also. However, cultivar Vs 22 suffered the highest seed damage and only Vs 46 showed damage index value statistically on par with it.

Studying various legume pod borer damage parameters in cowpea, Jackai (1982) concluded that flowers, pod and seed damage measurements provided the most important assessment of resistance to the pest.

Field screening for the resistance in the present study involved computation of plant resistance index (Ipr) based on flower, pod and seed damage parameters Vs 27 had the lowest Ipr value of 33.13 and was identified as the most resistant among the 51 cultivars. Cultivars with Ipr values not significantly different from Vs 27 were Vs 2, Vs 7, Vs 8, Vs 10, Vs 19, Vs 28, Vs 31 and Vs 35. The most susceptible cultivar was Vs 22 with the Ipr value of 109.37. The only other entry statistically on par with Vs 22 regarding resistance index value was Vs 46.

5.1.2 Correlations among parameters of damage

The results of correlation analysis done to determine the relationship between different damage parameters is presented in Table 3. There was no correlation between the larval count in flowers and pod damage measurements as well as seed damage index. After studying the relationship between various legume pod borer damage parameters in cowpea, Jackai (1982) reported that there was no correlation between number of larvae in flowers and seed damage index, so computed as in the present study. However he reported significant positive correlation between larval count in flowers and pod damage parameters.

In screening for damage to pods, the two methods employed in the present study viz., percentage pod infestation and pod damage severity appeared to give essentially similar results as evidenced from their correlation coefficient (r = 0.7729). This suggests that only one of the two pod damage measurements need to be measured in the screening programmes.

Pod damage severity as well as percentage pod infestation showed significant positive correlation with seed damage index. However, these findings are contrary to those reported by Jackai (1982) in his studies on cowpea resistance to legume pod borer.

5.1.3 Leaf chlorophyll content and legume pod borer resistance

The relationship between the total chlorophyll content of leaf tissues and plant resistance indices based on flower, pod and seed damage parameters was determined in the present study. Despite the variation in total leaf chlorophyll content ranging from 0.71 mg g^{-1} to 1.692 mg g^{-1}, the correlation coefficient (r = -0.0415) does not suggest any relationship between total leaf chlorophyll content and resistance to legume pod borer. Further the correlations between the pod damage parameters (percentage pod infestation and pod damage severity) and total leaf chlorophyll content were not significant (Table 5). This finding is contradictory to the significant positive correlation between total leaf chlorophyll contents and plant resistance indices reported by Oghiakhe (1992) and fails to support his suggestion to use the level of total leaf chlorophyll for classifying cultivars for resistance / susceptibility to legume pod borer.

5.1.4 Effect of pod width, non-glandular trichome density on pods and peduncle length on legume pod borer resistance

Significant differences among cultivars were present for pod width, non-glandular trichome density on pods and peduncle length (Table 6). The correlation coefficients of the above characters with Ipr and pod damage parameters are presented in Table 7.

Correlation analysis showed significant positive correlation of pod width with Ipr as well as both of the pod damage parameters viz., pod damage severity and percentage pod infestation indicating high susceptibility and severe pod damage for cultivars having pods with high width measurements Veda *et al.* (1975) observed positive correlation between pod width and infestation of pod fly in pigeon pea. Similarly Nawale and Jadhav (1983) reported that pod borer incidence on pigeonpea increased with increase in length and breadth of pods.

Non glandular trichomes are unicellular outgrowth with enlarged base and tapering towards the distal portion to form narrow, needle-like filiform tips. The trichomes become widely spaced as the pods grow and enlarge (Oghiakhe *et al.*, 1992 a). Hence, in this study, the non-glandular trichome counts were taken from pods at a particular growth stage, vegetable maturity stage i.e., eight days after flowering. Diffrences among cultivars in non-glandular trichome counts mm^{-2} of pod wall surface have been found to be significant.

The negative and significant correlation between non-glandular trichome density on pods and Ipr suggests it as a factor responsible for the resistance to legume pod borer in vegetable cowpea. The role of trichomes in plant resistance to pests has been reported by various workers (Pearson, 1958 ; Johnson, 1956 and Schillinger and Gallun, 1960). Resistance to *Clavigralla tomentosicollis* and *Maruca testulalis* in wild cowpea *Vigna vexillata* (Acc. TVNu 72) was partially attributed to pod wall trichomes (Chiang and Singh, 1988; Jackai and Oghiakhe, 1989).

Though the correlation of non-glandular trichome density with percentage pod infestation was non-significant, its correlation with pod damage severity was negative and significant. Pod damage severity is actually a measure of infestation sites per pod and more than three infestation sites were observed in the most severely damaged cultivars, Vs 46 and Vs 18. It is worthy to note that Vs 46 was, infact, one of the two cutlivars with the least non-glandular trichome count. It is logical to assume that the chances of multiple infestation on pods is considerably reduced as the non-glandular trichome density increases. Oghiakhe *et al.* (1992 a) opined that non-glandular trichomes impede movement of legume pod borer larvae and their sharp edges impale larvae to cause injury and death. This may be the reason for the decreasing pod damage severity with increasing non-glandular trichome count on pods as observed in the present study. The negative and significant correlations of non-glandular trichome density on pods with Ipr and pod damage severity observed in this study suggest the importance of utilization of this character in breeding for legume pod borer resistance in vegetable cowpea.

Despite the differences in peduncle length among cultivars, non significant correlation with Ipr showed that peduncle length does not play any significant role in the overall plant resistance to legume pod borer. Its correlations with both pod damage parameters were non-significant as well. However the present findings do not agree with the reported lesser legume pod borer damage in cowpea varieties with upright and long peduncle (Singh, 1978; van Emden, 1989).

5.2 Evaluation of yield and yield component characters

Selection of high yielding genotypes from among the identified partially resistant ones formed the next step in the present research programme. As yield and its component characters are quantitative in nature and influenced by environment in their expression, phenotypic selection is likely to be misleading. Efficiency of selection being dependent on the existing variability as well as heritability and interrelationships of characters, genetic analysis of yield and component characters is inevitable. The discussion that follows is based on the results of the field experiment conducted with this precise objective.

5.2.1 Variability studies

An estimate of the magnitude of variability present in a population is of great importance as it provides a basis for effective selection. The observed variability in a population is the total variation arising due to genotypic and environmental effects. But only the genetic component of total variability contributes to gain under selection. So knowledge on the nature and magnitude of genetic variation governing the inheritance of quantitative characters like yield and its components is essential (Allard, 1960).

In the present study significant differences were observed among the genotypes of vegetable cowpea for all the characters studied except length of main stem, number of primary branches and number of seeds per pod. Yield of vegetables per plant varied from 711.21 g (Vs 35) to 1797.73 g (Vs 14). Vs 14 and Vs 24 were identified as the top yielders.

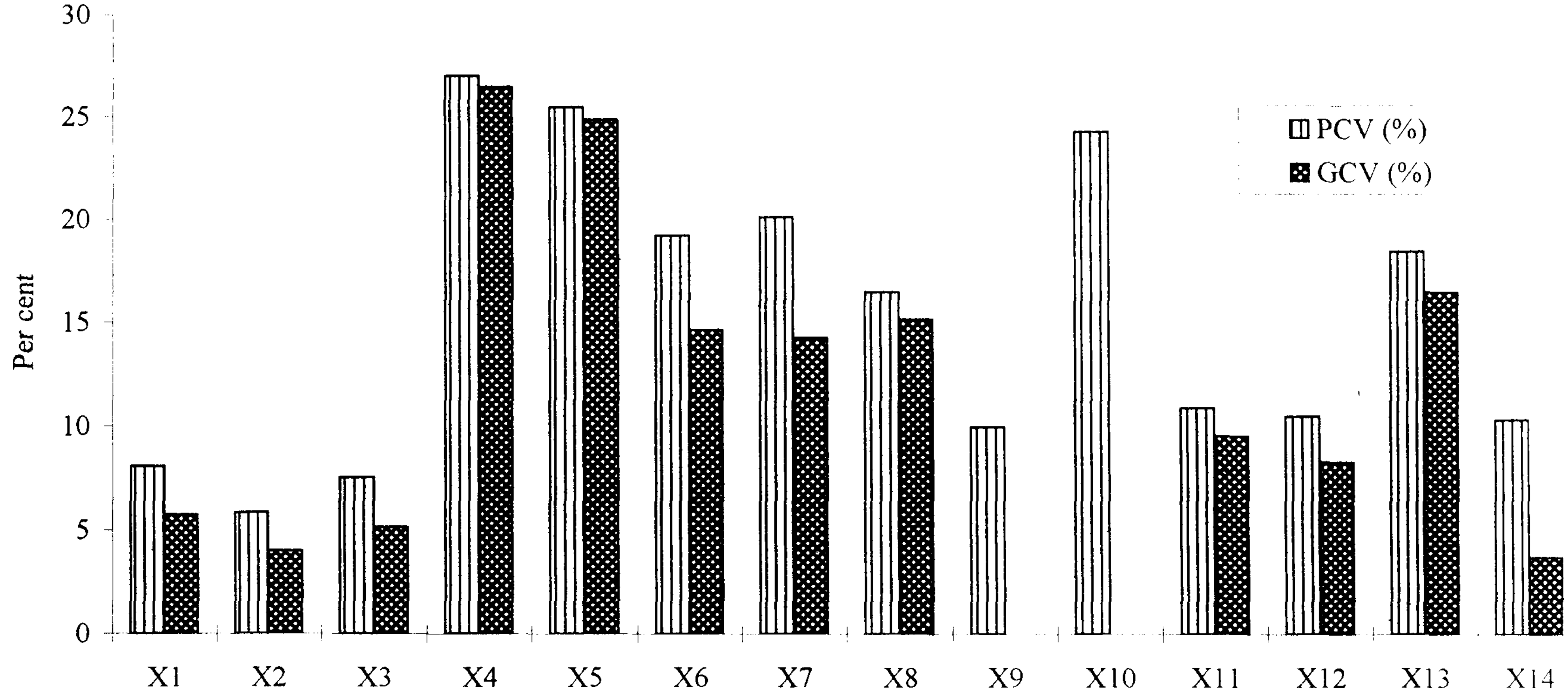
Existence of high variability for several characters in cowpea was reported by various workers (Pandita *et al.*, 1982; Yap, 1983; Sobha, 1994 and Resmi, 1998).

De Mooy (1985) observed high variability for flowering and number of pods per plant while Patil and Baviskar (1987) reported variability for pods per plant, pod clusters per plant and days to maturity. Results of the present investigation indicated the existence of substantial variability for different characters among vegetable cowpea varieties.

Coefficient of variation, phenotypic (PCV) and genotypic (GCV) are better indices for comparison of characters with different units of measurements. The GCV provides a valid basis for comparing and assessing the range of genetic diversity for quantitative characters and PCV measures the extent of total variation.

In the present study, GCV ranged from 4.01 percentage to 26.55 percentage. The highest GCV was for number of pods per plant. Yield of vegetable pods per plant, pod weight, length of peduncle, number of inflorescences per plant and number of pods per inflorescence also recorded

Fig. 1 Phenotypic and genotypic coefficients of variation for fourteen traits in vegetable cowpea



X1 - Days to first flowering
X2 - Days to first harvest
X3 - Length of harvesting period
X4 - Number of pods per plant
X5 - Yield of vegetables pods per plant

X6 - Number of inflorescences per plant
X7 - Number of pods per inflorescence
X8 - Length of peduncle
X9 - Length of mainstem
X10 - Number of primary branches

X11 - Pod length
X12 - Pod girth
X13 - Pod weight
X14 - Number of seeds per pod

high GCV. High GCV for number of pods per plant was reported by Singh and Mehndiratta (1969), Lakshmi and Goud (1977), Angadi *et al.* (1978), Ramachandran *et al.* (1980), Jana *et al.* (1982) and Sharma *et al.* (1988) in cowpea as in the present investigation. High GCV for vegetable pod yield was evident in this study. Similar results were reported by Sobha (1994) and Sreekumar *et al.* (1996) as in the present investigation. High estimates of GCV for number of inflorescence per plant was reported by Singh and Mehndiratta (1969), Angadi *et al.* (1978), Radhakrishnan and Jabraj (1982), Patil and Baviskar (1987).

Low estimates of GCV for days to first harvest, number of days to first flowering and harvesting period indicated limited scope for improvement of these traits due to low magnitude of heritable variation. Similar was the results obtained by Resmi (1998) in her study with 30 vegetable cowpea genotypes.

High values of PCV with correspondingly high values of GCV were observed in this study for number of pods per plant, yield of vegetable pods per plant, number of pods per inflorescence, number of inflorescences per plant and pod weight which indicated the presence of high degree of genetic variation and better scope for improvement of these characters through selection. Patil and Baviskar (1987) reported high PCV as well as GCV for number of pods clusters per plant. Similar results were reported by Resmi (1998) for vegetable pod yield per plant. She obtained high values for GCV as well as PCV for pod weight and pods per inflorescence.

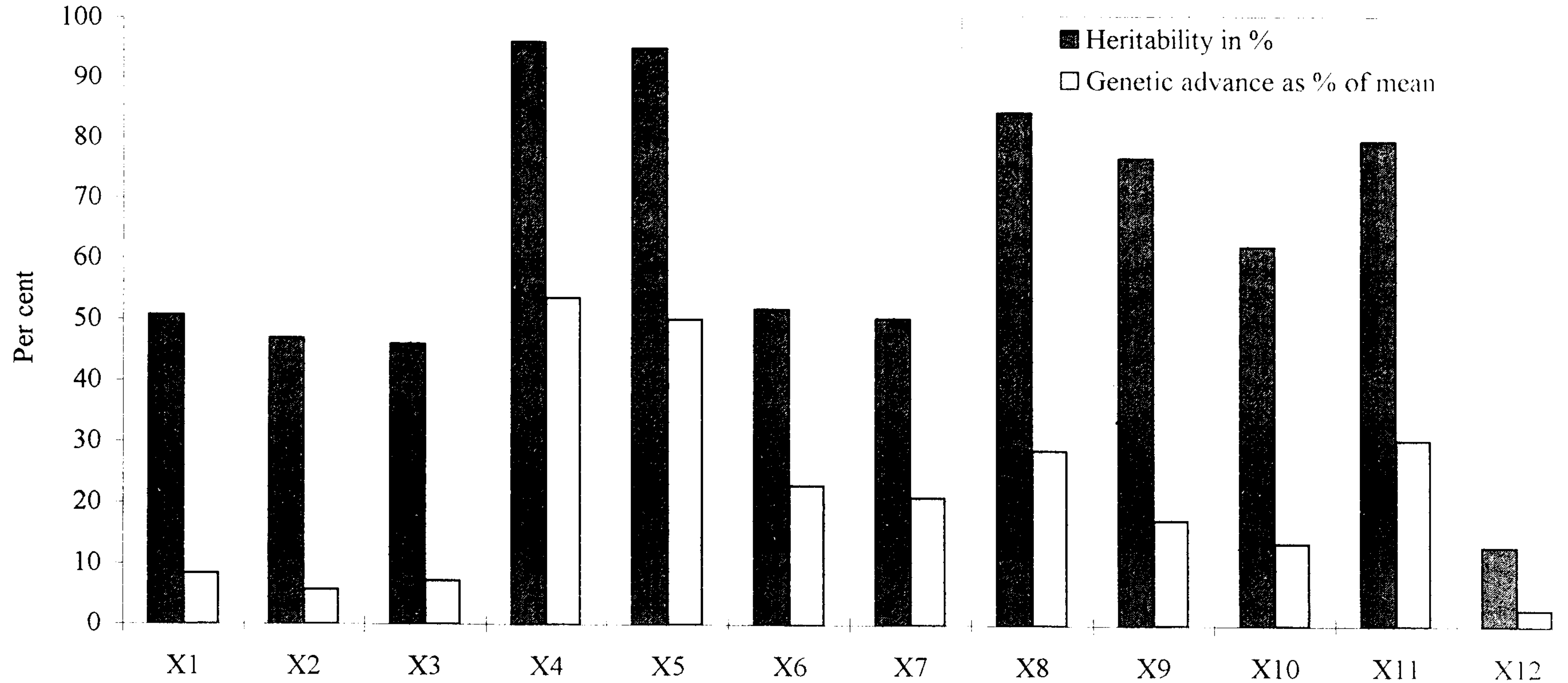
The difference between PCV and GCV was maximum for number of pods per inflorescence followed by number of inflorescences per plant, length of harvesting period, days to first flowering and pod girth revealing the profound influence of environment on these characters. The differences between GCV and PCV were low for the characters such as number of pods per plant, yield of vegetable pods per plant, length of peduncle and pod length. This indicates that the variation observed in these characters were mainly due to genetic cause and environment had only negligible influence over them. Sreekumar *et al.* (1996) reported low environmental influence on pod length in conformity with the above results. However, their report on low environmental influence on days to flowering is contradictory to the present findings.

From the foregoing discussion it is clear that number of pods per plant and yield of vegetable pods per plant are characters that offer scope for selection.

5.2.2 Heritability and genetic advance

The total variability existing in a population is the sum total of heritable and non-heritable components. While selecting for a character, consideration of mere phenotypic variability without estimating the heritable part of it will not be of much use. The magnitude of heritability indicates the effectiveness with which the selection of genotype can be made based on phenotypic performance (Johansen *et al.*, 1955). Allard (1960) suggested that gain from selection for a particular character depends largely on the heritability of the

Fig. 2 Heritability and genetic advance for twelve traits in vegetable cowpea



X1 - Days to first flowering
X2 - Days to first harvest
X3 - Length of harvesting period
X4 - Number of pods per plant
X5 - Yield of vegetables pods per plant
X6 - Number of inflorescences per plant

X7 - Number of pods per inflorescence
X8 - Length of peduncle
X9 - Pod length
X10 - Pod girth
X11 - Pod weight
X12 - Number of seeds per pod

character. Burton (1952) suggested that GCV along with heritability would provide a picture of the amount of advance to be expected by phenotypic selection.

In the present study, the characters, viz., number of pods per plant, yield of vegetable pods per plant, length of peduncle, pod weight, pod length and pod girth recorded high heritability. This may be due to the fact that these characters are least influenced by environmental effects and there could be greater correspondence between phenotypes and breeding value while selecting individuals (Johansen *et al.*, 1955). Moderate values of heritability were recorded for number of inflorescences per plant, days to first flowering, number of pods per inflorescence, days to first harvest and length of harvesting period. Number of seeds per pod recorded low heritability.

High heritability for pod yield per plant in the present study showed agreement with the findings of Sobha (1994) and Resmi (1998). Similarly high heritability had earlier been reported for number of pods per plant (Damaramy, 1994; Resmi, 1998), peduncle length (Rajendran *et al.*, 1978; Resmi, 1998) as well as length, weight and girth of pods (Sobha, 1994; Resmi, 1998). Contrary to the findings of the present study, Yap (1983) and Sharma *et al.* (1988) found low heritability for pod yield while Rajendran *et al.* (1979) and Sreekumar *et al.* (1996) reported high heritability for number of seeds per pod.

High heritability estimates indicate the effectiveness of selection based on good phenotypic performance but does not necessarily mean a high genetic gain for a particular character. Johansen *et al.* (1955) pointed out that high heritability estimates along with high genetic advance would be useful than heritability values alone in predicting the resultant effect of selecting the best individual.

High values of genetic advance as percentage of mean were recorded in this study by number of pods per plant followed by pod yield per plant, pod weight, length of peduncle, number of inflorescences per plant and number of pods per inflorescence. Resmi (1998) showed high GA for the above characters. The present findings are supported by the corroborative reports of high GA for number of pods per plant (Angadi *et al.*, 1978; Ramachandran *et al.*, 1980; Ram *et al.*, 1994; Sreekumar, 1995), vegetable pod yield per plant (Angadi *et al.* (1978); Pandita *et al.* (1982); Vaid and Singh (1983); Sobha (1994) and pod weight (Sobha, 1994).

Characters with high heritability and high genetic advance are controlled by additive gene action and therefore amenable to genetic improvement through selection (Panse, 1957). In the present study high values of heritability estimates coupled with high genetic advance were recorded for number of pods per plant, yield of vegetable pods per plant and pod weight. Similar results were obtained by Pandita *et al.* (1982); Vaid and Singh (1983); Sobha (1994) and Resmi (1998) for yield per plant in cowpea. Ram *et al.* (1994) and Sobha (1994) reported high genetic advance as well as heritability for pods per plant and pod weight respectively in cowpea.

5.2.3 Correlation studies

Yield is a complex character, which is the outcome of a number of genetic factors and the environmental conditions occurring at various stages of plant growth. Therefore selection for this character merely on the basis of phenotypic expression is likely to be misleading. Hence analysis of yield in terms of genotypic, phenotypic and environmental correlation coefficients of component characters leads to the understanding of characters that can form the basis of selection.

Correlation provides information on the nature and extent of relationship between all pairs of characters. So when the breeder applies selection, it not only improves that particular trait, but also those characters associated with it. The genotypic correlation between the characters provide a reliable measure of the genetic association between them and helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1981).

In the present investigation, the characters which strongly contributed to pod yield per plant were number of seeds per pod ($r = 1.0103$) followed by number of pods per plant ($r = 0.835$) and length of harvesting period ($r = 0.6436$). The earlier reports of high positive correlation of number of seeds per pod with vegetable pod yield (Sobha, 1994; Sreekumar *et al.*, 1996) and number of pods per plant with vegetable pod yield (Sreekumar *et al.*, 1996; Resmi, 1998) supported the present findings.

In this study high negative correlation for vegetable pod yield were obtained with days to first flowering, days to first harvest and number of inflorescences per plant. This indicates that selection for vegetable pod yield will adversely affect number of inflorescences per plant and leads to early flowering and harvest. Contrary to the above findings, positive correlation of vegetable pod yield with days to harvest was reported by Sobha (1994) and with number of inflorescence per plant by Sreekumar *et al.* (1996).

High positive genotypic and phenotypic correlation coefficients of pod yield with number of seeds per pod, number of pods per plant and length of harvesting period indicate that selection based on any one of the above characters may also result in the improvement of pod yield in vegetable cowpea.

A higher positive environmental correlation coefficient between pod yield and number of pods per plant indicates the strong influence of environment on these characters.

In general, for the characters studied phenotypic correlations were smaller than genotypic correlations which indicated that environment had small effects on those characters.

For selection based on yield components to be more successful, data on inter-relationships among the yield components are necessary, as it gives a more reliable information rather than a knowledge on association between yield and its components alone.

Days to first flowering had positive and strong correlation with days to first harvest (r = 0.9784). This was in conformity with the findings of Perrino *et al.* (1993) and Resmi (1998) in cowpea. Days to first flowering also showed high positive correlation with number of inflorescences per plant (r = 0.5169). This was similar to the findings of Singh and Mehndiratta (1969) in cowpea. In the study, correlation between days to first flowering and number of seeds per pod was negative. However positive correlation between days to first flowering and number of seeds per pod was reported by Shakarad *et al.* (1995) and Sreekumar *et al.* (1996) in cowpea.

Pod length exhibited negative association with number of seeds per pod. However significant positive correlation between the two characters was reported by Tamilselvam and Das (1994), Resmi (1998) and Sreekumar *et al.* (1996).

High positive correlation was obtained between number of pods per plant and number of seeds per pod. But, the results obtained by Patil and Bhapkar (1987) in cowpea was contradictory to this. Number of pods per plant had negative correlation with number of days to first flowering and harvest. Similar findings were obtained by Sreekumar *et al.* (1996) in vegetable cowpea.

5.2.4 Path analysis

Selection based on yield alone is not very efficient but that based on its components as well could be more efficient (Evans, 1978). Path coefficient analysis provides a knowledge of the paths through which a component character influences the expression of an economic character like yield. It helps in partitioning the genotypic correlation coefficients into direct and indirect effects of the component characters on yield.

As per the results of the investigation maximum direct effect on yield was contributed by days to first flowering (0.9228) followed by number of pods per plant (0.8202). For days to first flowering direct effect was high and positive while total correlation was negative. This may be due to the high indirect effect of this character through other components such as day to first harvest and number pods per plant.

Direct effect of days to first harvest was negative and high and its correlation with yield was also the same. The high positive indirect effect via days to first flowering nullified the direct effect of days to first harvest.

Direct effect of length of harvesting period was low and negative while total correlation was positive and high. This high correlation with yield may be due to positive indirect effect via days to first harvest and number of pods per plant on yield.

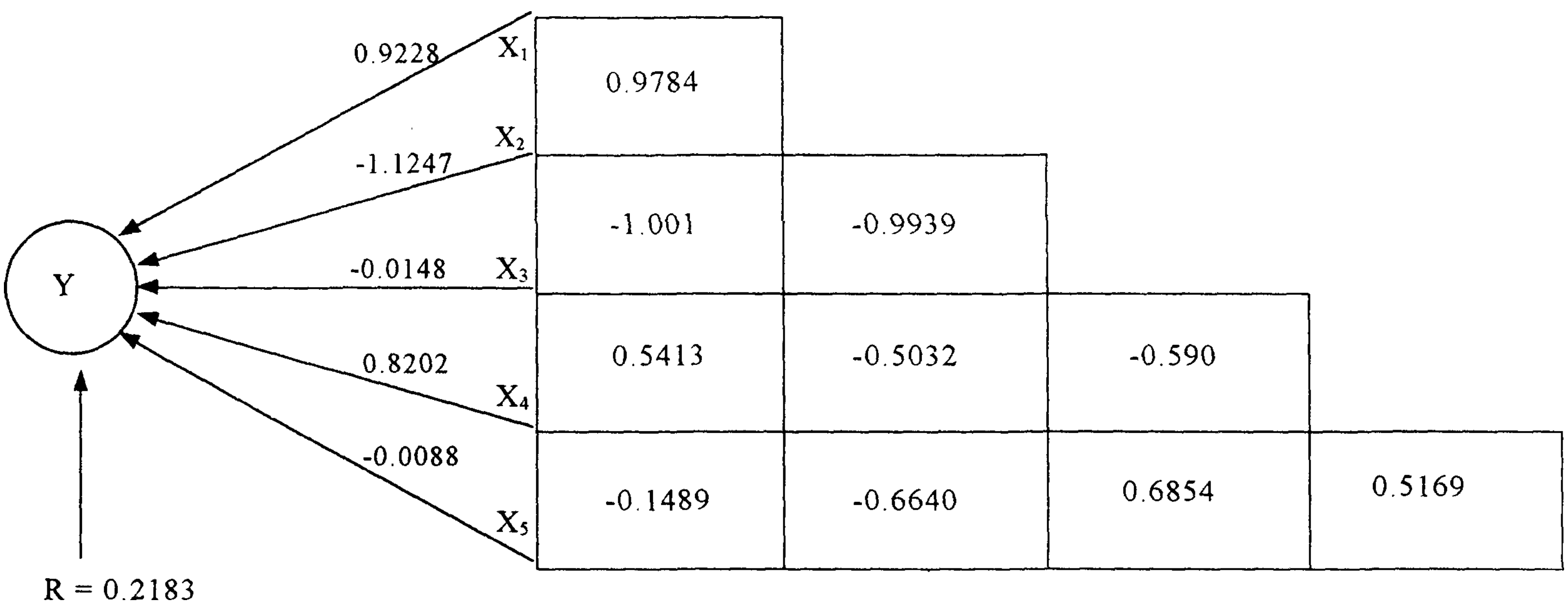
Number of pods per plant had high direct effect (0.8202) as well as high positive correlation (0.8350) with yield. This is in conformity with the results of Jana *et al.* (1983), Obisesan (1985), Patil and Baviskar (1987), Tamilselvan and Das (1994) and Resmi (1998). However Birader *et al.* (1991) obtained negative direct effect for pod per plant on yield in cowpea. So correlation explains true relationship of number of pods per plant and yield.

Number of inflorescences per plant recorded negative correlation as well as low negative direct effect. High direct effect of inflorescences per plant with vegetable pod yield was reported by Biradar *et al.* (1991) and Tamilselvan and Das (1994).

Hence days to first flowering, days to first harvest and number of pods per plant can be considered during selection programmes for identifying yielding vegetable cowpea varieties.

The residue obtained was low (0.2183) indicating that the component characters taken for path analysis well explained the cause and effect system.

Fig. 3 Path diagram showing direct and indirect effects of the components on yield



X_1 - days to first flowering
X_2 - days to first harvest
X_3 - Length of harvesting period
X_4 - No. of pods per plant
X_5 - No. of inflorescence per plant

5.3 Promising cultivars identified based on legume pod borer resistance and yield performance

From the results of the two field experiments, it was found that two cultivars, viz., Vs 14 and Vs 24, among the 15 partially resistant ones subjected to yield evaluation gave higher vegetable pod yield. As far as yield is concerned, Vs 14 and Vs 24 stood in the first and second position respectively. These varieties can be considered as suitable for cultivation in legume pod borer endemic areas especially if an integrated pest management approach is adopted. The cultivar Vs 27 which ranked first in legume pod borer resistance was one of the low yielders among the lot. Further, it was found that the top ranking cultivars with respect to legume pod borer resistance were, in general, low yielding. These cultivars with relatively high level of resistance can be utilized in legume pod borer resistance breeding programmes in vegetable cowpea.

SUMMARY

6. SUMMARY

The present studyc for the evaluation of vegetable cowpea (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt) for legume pod borer, *Maruca vitrata* (Fab.) resistance and yield comprising of two field experiments was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 1997-1999.

In experiment I fifty local cultivars collected from different parts of Kerala and an improved variety, Sharika were screened for pod borer resistance in a randomised block design with two replications. Measures were taken for selective elimination of non-target pests and to build up legume pod borer population in the screening field.

Assessment of hostplant resistance was done through the computation of overall plant resistance index (Ipr) based on flower, pod and seed damage parameters, viz., number of larvae per 25 flowers, percentage pod infestation and seed damage index (Jackai, 1982). Pod damage severity in terms of number of larval entry / exit holes per pod was also determined.

Significant differences among the cultivars were observed for all the above mentioned parameters employed for damage assessment. Flower infestation was high for Vs 33 and lowest for Vs 27. Cultivars Vs 2 and Vs 28 recorded the lowest percentage pod infestation as well as pod damage severity. Highest percentage pod infestation was observed in Vs 51. Most severe pod damage was observed for Vs 46 and Vs 18. Cultivars Vs 13 and Vs 22 had the lowest and highest seed damage index values respectively.

There were significant differences among the cultivars in plant resistance index values. Lower Ipr values indicate higher level of plant resistance. Vs 27 with the lowest Ipr value was identified as the most resistant among the 51 cultivars. Vs 2, Vs 7, Vs 8, Vs 10, Vs 19, Vs 28, Vs 31 and Vs 35 were on par with Vs 27. Vs 22 was the most susceptible variety and was on par with Vs 46.

Correlation analysis was done to determine the relationships between different damage parameters. Non-significant correlation between flower and seed damage parameters suggested that flower and seed damages were unrelated. Pod damage criteria viz., percentage pod infestation and pod damage severity showed highly significant positive correlation between them but were uncorrelated with larval count in flowers. Pod damage, irrespective of the criterion of assessment, was found to be positively correlated with seed damage.

There were significant differences between cultivars in total leaf chlorophyll content. Non-significant correlation between leaf chlorophyll content and Ipr values indicated the absence of any relationship between them. The correlation between total leaf chlorophyll content and pod damage parameters were non-significant as well.

Pod width, non-glandular trichome density on pods and peduncle length were found to exhibit significant differences among the cultivars. Pod width was found to be positively correlated with Ipr, pod damage severity and percentage pod infestation. Correlation between peduncle length and damage parameters were not significant. Non-glandular trichome density recorded significant negative correlation with Ipr and pod damage severity indicating that plant resistance increases with increase in non-glandular trichome density on pods.

In experiment II, 15 partially resistant cultivars selected from experiment I based on Ipr values were evaluated for yield and yield component characters. The experiment was conducted in RBD with three replications. Observations were recorded on 14 characters i.e., days to first flowering, days to first harvest, length of harvesting period, length of peduncle, number of inflorescences per plant, number of pods per inflorescence, number of pods per plant, yield of vegetable pods per plant, pod length, pod girth, pod weight and number of seeds per pod. The data collected were subjected to analysis of variance and the genetic parameters like variability, heritability, genetic advance, correlation coefficients and path coefficients were estimated.

The analysis of variance revealed significant differences among the genotypes of all the characters under study except length of main stem, number of primary branches and number of seeds per pod. The cultivars Vs 14 was the top yielder of green pods. Highest pod length was exhibited by Vs 28 and highest pod weight by Vs 2.

The PCV as well as GCV were maximum for pods per plant followed by yield of vegetable pods per plant.

Heritability estimates of characters ranged from 12.97 to 96.12 per cent. High values of heritability coupled with high genetic advance were recorded for number of pods per plant, yield of vegetable pods per plant, pod weight and length of peduncle.

At genotypic level, pod yield per plant was positively correlated with number of seeds per pod, number of pods per plant, length of harvesting period, number of pod per inflorescence, pod weight and pod length. Number of seeds per pod had the maximum genotypic association with yield.

Number of pods per plant had high direct effect as well as significant positive correlation with yield. Hence number of pods per plant should be given due stress in breeding programmes for developing high yielding vegetable cowpea varieties.

In view of the superior yield performance of the partially resistant cultivars, viz., Vs 14 and Vs 24 it is inferred that they may be useful for cultivation in legume pod borer endemic areas. Further, varieties with high degree of legume pod borer resistance identified in the present study can be utilized for legume pod borer resistance breeding programmes in vegetable cowpea.

REFERENCES

REFERENCES

Allard, R. W. 1960. *Principles of Plant Breading*. John Wiley and Sons. Inc. New York, p. 485

Ananthakrishnan, T. N. 1992. *Dimensions of Insect - Plant Interactions*, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, p. 184

Angadi, P.S., Subramani, A. and Kulkarni, R.S. 1978. Genetic variability for some quantitative traits in cowpea. *Agric. Res. J. Kerala.* **16** (1) : 60-62

Anithakumari. 1992. Host resistance in cowpea (*Vigna unguiculata* L. Walp) to pod borer, *Maruca testulalis* (Geyer). *Msc (Ag.) thesis*. Kerala Agric. Univ., Thrissur

Anonymous. 1996. Annual Report for 1994-96 of the project 'Monitoring of residues of insecticides in vegetables collected from markets in Kerala'. College of Agriculture, Vellayani

*Attachi, P. and Djihou, Z. C. 1994. Record of host-plants of *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae) in Republic of Benin. *Annales de la Societe Entomologique de France* **30** (2) : 169-174

Batra, G. R. and Gupta, D. S. 1970. Screening of varieties of cotton for resistance to jassids. *Cotton Growing Review* **47** : 285

Beck, S. D. 1965. Resistance of plants to insects. *Ann. Rev. Entomol.* **10** : 207-232

Benedict, J. H., Leigh, T. F. and Hyer, A. H. 1983. *Lygus hesperus* (Heteroptera : Miridae) oviposition behaviour, growth and survival in relation to cotton trichome density. *Environ. Entomol.* **12** : 331-335

Bindra, O. S. and Sagar, P. 1976. Composition of Vita - 1 a pest resistant cowpea with local cultivars under different sowing dates and distance with minimal pesticide resistance application. *Trop. Grain Legume Bull.* **6** : 8-9

Biradar, B.D., Goud, J.V. and Patil, S.S. 1991. A study on character association and path coefficient in cowpea. *J. Maharashtra agric. Univ.* 16(1): 27-29

Bottenberg, H, Tamo, M., Arodokoun, D., Jackai, L.E.N., Singh, B.B. and Youm, O. 1997. *Advances in cowpea reserch*, IITA, Ibadan, Nigeria p. 384

*Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassland Congr.*, 1 : 277-283

Chakraborti, A. K. 1986. Cowpea. In *Vegetable Crops* pp. 603 - 611 (eds. T. K. Bose, M. G. Som and J. Kabir) Naya Prokash, Calcutta

Chatterji, S. M., Sarup, P., Bhanburkar, M. W., Marwaha, K. K., Panwar, V.P.S. and Siddique, K.H.. 1971. Relative susceptibility of some promising exotic maize material to *Chilo zonellus* Swinhoe under artificial infestations. *Indian J. Ent.* **33** : 209-213

Chiang, H. S. and Jackai, L.E.N. 1988. Tough pod wall : a factor involved in cowpea resistance to pod sucking bugs. *Insect Sci. Appl.* **9** : 389-393

*Chiang, H. S. and Singh, S. R. 1988. Pod hairs as a factor in *Vigna vexillata* resistance to pod sucking bug, *Clavigralla tomentosicollis*. *Entomologia Experimentalis et Applicata* **47** : 195-199

Dabholkar, A. R. 1992. Elements of biometrical genetics, Concept publishing company, New Delhi, p. 431

Dabrowski, Z. T., Bungu, M. and Ochieny, R. S. 1983. Studies on the legume pod-borer, *Maruca testulalis* (Geyer) - III. Methods used in cowpea screening for resistance. *Insect Sci. Appl.* **4** : 141-145

Damaramy, A.M. 1994. Estimates of genotypic and phenotypic correlation and potence of geneset in cowpea (*Vigna unguiculata* (L.) Walp). *Assiut J. agric. Sci.* 25 (4) : 1-8

De Mooy, B.E. 1985. Variability of different characteristics in Botswana cowpea germplasm. *Tropical Grain Legume Bull.* 31: 1-4

Dent, D. 1991. *Insect Pest Management.* CAB International, Wallingford, p. 604

Dent, D. R. 1995. *Integrated Pest Management.* Chapman and Hall, London, p. 356

Dewey, D. R. and Lu, K. H. 1959. *Agron. J.* **51** : 515-518

van Emden, H. F. 1987. Cultural methods : the plant. In *Integrated Pest Management* (Eds. A. J. Burn, T. H. Coaker and P. C. Jepson) 27-68, Academic Press, London

van Emden, H. F. 1989. *Pest Control.* Edward Arnold, London p. 117

Evans, L. T. 1978. *Crop Physiology.* Cambridge University Press, Cambridge, London, p. 355

Eveleens, K. G., van den Bosch, R., Ehler, L. E. 1973. Secondary outbreak induction of beet armyworm by experimental insecticide applications in Cotton in California. *Enviorn. Entomol.* **2** : 497-503

Everson, E. H. and Gallun, R. L. 1980. Breeding approaches in wheat. In : *Breeding Plants Resistant to Insects* (Eds. F. G. Maxwell and P. R. Jennings), 513-533, Wiley, New York

Ezueh, M. I. 1981. The biological base of resistance in cowpea to the cowpea moth, *Cydia ptychora* (Lepidoptera : Olethreutidae). *Ann. appl. Biol.* **99** (3) : 313-321

Ezueh, M. I. and Taylor, T. A. 1981. Field resistance in cowpea, *V. unguiculata* to the cowpea moth, *Cydia ptychora*. *Ann. appl. Biol.* **99** (3) : 307-312

Falconer, D.S. 1981. *Introduction to quantitative Genetics* (3rd Edn.) Longman, New York, p. 438

Gallun, R. L., Roberts, J. J., Finny, R. E. and Patterson, F. L. 1973. Leaf pubescence of field grown wheat : a deterrent to oviposition by the cereal leaf beetle. *Journal of Environmental Quality* **2** : 333-334

Gatehouse, J. A. 1991. Breeding for resistance to insects. In *Advanced Methods in Plant Breeding and Biotechnology* (Ed. D. R. Murray). 250-276, CAB International, Wallingford, U. K.

Guthrie, W. D. and Carter, S. W. 1972. Back crossing to increase survival of larvae of a laboratory culture of the European corn borer on field corn. *Ann. Entomol. Soc. Am.* **65** : 108-109

Hammond, R. B. and Cooper, R. L. 1989. Development and antibiosis of released soybean germplasm lines resistant to Mexican bean beetle (Coleoptera : Coccinellidae). *J. Econ. Ent.* **82** (1) : 259-263

*Harms, C. T. 1983. Genetic engineering and tissue culture in crop protection. Proc. 10th *Int. Congr. Pl. Prot.*, Brighton, 1983 **2** : 810-819

*Hsiao, T. H. 1969. Chemical basis of host selection and plant resistance in oligophagous insects : *Entomologia Experimentalis et applicata* **12** : 777-788

IITA (International Institute of Tropical Agriculture) 1981. Annual report for 1980, Ibadan, Nigeria

Ishaaya, I. 1986. Nutritional and allelochemic insect - plant interactions relating to digestion and food intake : Some examples pp. 191-223 in J. R. Miller and T. A. Miller (Eds.) *Insect - plant interactions.* Springer- Verlag, New York

Jackai, L.E.N. 1982. A field screening technique for resistance of cowpea (*Vigna unguiculata*) to the pod-borer *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae). *Bull. Ent. Res.* **72** : 145-156

*Jackai, L.E.N. 1983. Efficacy of insecticide application at different times of day against legume pod borer, *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae) on cowpea in Nigeria. *Protection Ecology* **5** : 245-251

Jackai, L.E.N., A.R. Pannizzi, G.G.Kundu and K.P. Srivastava. 1990. Insect pests of soyabean in the tropics. *Insect pests of tropical food legumes.* (Ed) S.R.Singh, John Wiley and Sons, Chichester, U.K pp. 91-156.

Jackai, L.E.N. and Adalla, C. B. 1997. Pest management practices in cowpea : a review. In *Advances in cowpea research.* (Eds. B. B. Singh, D. R. Mohan Raj, Dashiell, K. E. and Jackai, L. E. N) pp. 240-258. IITA, Nigeria

Jackai, L.E.N. and Oghiakhe, S. 1989. Pod wall trichomes and their role in the resistance of two wild copwea, *Vigna vexillata,* accessions to *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae) and Cl*avigralla tomentosicollis* Stal (Hemiptera : Coreidae). *Bull. Ent. Res.* **79** : 595-605

Jackai, L.E.N., Singh, S. R. 1988. Screening techniques for host plant resistance to cowpea insect pests. *Trop. Grain legume Bull.* **35** : 2-18

Jain, J. P. 1982. Statistical Techniques in Quantitative Genetics. Tata Mc Graw Hill Co., New Delhi, p. 281

Jana, S., Som, M.G. and Das, M.D. 1982. Genetic variability and correlation studies in cowpea. *Veg. Sci.* 9 (2): 96-107

Johnson, B.1956. The influence of aphids on the glandular hairs of tomato plants. *Pl. Path.* 5: 131-132

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimates of genetical and environmental variability in soyabeans. *Agron. J.* **47** : 314-318

*Khaemba, B. M. 1985. Search in the available cowpea germplasm for sources of resistance to the common pod sucking bugs, *Riptortus dentipes* (F.) and *Anoplocnemis curvipes* (F.). *East African Agril. and Forestry J.* **50** (1/4) : 1-5

Knight, R. L., Keep, E., Briggs, J. B. and Parker, J. J. 1974. Transference of resistance to black-currant gall mite, *Cecidophyopsis ribis,* from gooseberry to black currant. *Ann. appl. Biol.* **76** : 123-130

Kogan, M. 1994. Plant resistance in pest management pp. 73-128 in R. L. Metcalf and W. H. Luckmann (Eds.). *Introduction to insect pest management.* John Wiley and Sons. Inc., New York

Kogan, M. and Ortman, E. E. 1978. Antixenosis - a new term proposed to replace Painter's 'non-preference' modality of resistance, *Bull. Ent. Soc.* America **24** : 175-176

Kumar, P., Prakash, R. and Haque, M.F.1976. Interrelationships between yield and yield components in cowpea (*Vigna sinensis* L.). *Proc. Bihar Acad. agric Sci.* 24(2): 13-16

Kumar, R. 1984. *Insect Pest Control with Special Reference to African Agriculture*, Edward Arnold, London pp. 307

Lakshmi, P. V. and Goud, V. 1977. Variability in cowpea (*Vigna sinesis* (L.)). *Mysore J. agric. Sci.* **11** : 144-147

Lall, G. and Sukhani, T. R. 1982. Antibiotic effect of some resistant lines of sorghum on post larval development of *Chilo partellus* (S.). *Indian J. agric. Sci.* **52** (2) : 127-129

*Leszczynski, B., Warchol, J. and Niraz Seweryn. 1985. The influence of phenolic compounds on the preference of winter wheat cultivars by cereal aphids. *Insect Sci. Appl.* **6** (2) : 157-158

Levin, B. R. 1979. Problems and promise in genetic engineering in its potential applications to insect management. In *Genetics in relation to Insect Management* (Eds. M. A. Hoy and J. J. McKelvey. Jr.) 170-175, Rockfeller Foundation, New York

*Levin, D. A. 1971. Plant phenolics : an ecological perspective. *American Naturalist* **105** : 157-181

Lukefahr, M. J. and Houghtaling, J. E. 1969. Resistance of cotton strains with high gossypol content to *Heliothis* spp. *J. Econ. Ent.* **62** : 588-591

Lukefahr, M. J. and Martin, D. F. 1966. Cotton plant pigments as a source of resistance to boll worm and tobacco budworm, *J. Econ. Ent.* **59** : 176-179

Lukefahr, M. J., Houghtaling, J. E. and Graham, H. M. 1971. Suppression of *Heliothis* populations with glabrous cotton strains. *J. Econ. Ent.* **64** : 486-489

Lukefahr, M. J., Martin, D. F. and Mayer, J. R. 1965. Plant resistance to five Lepidoptera attacking cotton. *J. Econ. Ent.* **58** : 516-518

Macfoy, C. A., Dabrowoski, Z. T. and Okech, S. 1983. Studies on the legume pod borer, *Maruca testulalis* (Geyer) - VI. Cowpea resistance to oviposition and larval feeding. *Insect Sci. Appl.* **4** : 147-152

Miller, P.A., Williams, V.C., Robinson, H.P. and Comstock, R.E. 1958. Estimates of genotypic and environmental variances and covariances in upland cotton and their implication in selection. *Agron. J.*, 5: 126-131

Murthy, J. 1982. Path analysis and selection indices in three F_2 populations of cowpea (*Vigna unguiculata* L. Walp). *Thesis Absts.* Univ. agric. Sci. Bangalore. 8(4): 893-4

Navasero, R. C. and Ramaswamy, S. B. 1991. Morphology of leaf surface trichomes and its influence on egg laying by *Heliothis virescens*, *Crop Science* **31** : 342-353

Nawale, R. N. and Jadhav, L. D. 1983. Relative susceptibility of some varieties of pegionpea to pod borers. *J. Maharashtra agric. Univ.* **8** (1) : 94-95

Norris, D. M. and Kogan, M. 1980. Biochemical and morphological bases of resistance pp. 23-62. In F. G. Maxwell and P. R. Jennings (Eds.). *Breeding plants resistant to insects*, John Wiley and Sons, New York

*Obisesan, I. O. 1985. Association among grain yield components in cowpea. *Genetica Agraria* **39** (4) : 377-380

Ofuya, T. I. and Akingbohunbe, A. E. 1986. Aspects of varietal resistance in cowpea to the black cowpea moth, *Cydia ptychora* (Meyrick) (Lepidoptera : Tortricidae). *Insect Sci. Appl.* 7 (6) : 777-780

Oghiakhe, S. 1992. The relationship between leaf chlorophyll and cowpea resistance to the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *Journal of Plant Protection in the Tropics* **9** (3) : 201-207

Oghiakhe, S., Jackai, L. E. N., Makanjuola, W. A. and Hodgson, C. J. 1992 a. Morphology, distribution and role of trichomes in cowpea (*Vigna unguiculata*) resistance to legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *Bull. Ent. Res.* **82** : 499-505

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W. A. 1992 b. A rapid visual field screening technique for resistance of cowpea (*Vigna unguiculata*) to legume pod borer *Maruca testulalis* (Lepidoptera : Pyralidae). *Bull. Ent. Res.* **82** : 507-512

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W. A. 1992c. Pod wall toughness has no effect on cowpea resistance to legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *Insect Sci. Appl.* **13** : 345-349

Oghiakhe, S., Jackai, L. E. N., Makanjuola, W. A. 1992 d. Cowpea plant architecture in relation to infestation and damage by legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae) : 2. Effect of pod angle. *Insect Sci. Appl.* **13** : 339-344

Oghiakhe, S., Jackai, L.E.N., and Makanjuola, W. A. 1991. Cowpea plant architecture in relation to infestation and damage by legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae) : 1. Effect of canopy structure and pod position. *Insect Sci. Appl.* **12** : 193-200

Oghiakhe, S., Makanjuola, W. A. and Jackai, L.E.N. 1993. The relationship between the concentration of phenol in cowpea and field resistance to legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *International J. of Pest Management* **39** : 261-264

Okech, S. H. O. and Saxena, K. N. 1990. Responses of *Maruca testulalis* (Lepidoptera : Pyralidae) larvae to variably resistant cowpea cultivars. *Environ. Entomol.* **19** (6) : 1792-1797

Painter, R. H. 1951. *Insect Resistance in Crop Plants.* Macmillan, New York, pp. 520

Panda, N. 1979. *Principles of host plant resistance to insect pests* : Hindustan Publishing Corporation, Delhi, p. 386

Pandita, M. L., Vasishta, R. N., Bhutani, R. D. and Batia, B. R. 1982. Genetic variability studies in cowpea (*Vigna sinensis* (L.) Savi) under dry farming conditions. *HAU J. Res.* **12** (2) : 241-245

Panse, V.G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.*, 17 : 318-328

Pathak, M. D. 1970. Genetics of plants in pest management. pp. 138-157. in R. L. Rabb and F. E. Guthrie (Eds.) *Concepts of Pest Management*, North Carolina State University, Raleigh

*Pathak, M. D. 1977. Defence of rice crop against insect pests. *Annals of New York Academy of Science*, p. 287

Pathak,M.D., Andres,F., Galacgac, N.and Raros, R. 1971. Resistance of rice varities to striped rice borers. *Int. Rice Res. Inst. Tech. Bull.* 11:69

Pathak, M. D. and Saxena, R. C. 1980. Breeding approaches in rice pp. 422-455 in Maxwell, F. G. and Jennings, P. R. (Eds.). *Breeding plants resistant to insects.* Wiley, New York

Pathak, M. D., Andres, F., Galacgac, N. and Raros, R. 1991. Resistance of rice varieties to striped rice borers. *Int. Rice Res. Inst. Tech. Bull.* **11** : 69

Patil, R. B. and Baviskar, A. P. 1987. Variability studies in cowpea. *J. Maharashtra agric Univ.* **12** (1) : 63-66

Patil, R. B. and Bhapkar, D. G. 1987. Correlation studies in cowpea. *J. Madras agric. Univ.* **12** : 56-59

Perrin, R. M. 1978. Varietal differences in the susceptibility of cowpea to larvae of seed moth, *Cydia ptychora* (Meyrick) (Leprodoptera : Totricidae). *Bull. Ent. Res.* **68** (1) : 47-56

Perrino, P., Laghetti, G., Zeuli, P. L. S., Monti, L. M., Spagnoletti - Zeuli, P. L. 1993. Diversification of cowpea in the Mediterranean and other centers of cultivation. *Genetic Resources and Crop Evolution* **40** (3) : 121-132

Person, E.D.1958. *The Insect Pests of Cotton in Tropical Africa.* London, Eastern press. p.355

Purseglove, J. W. 1968. *Tropical Crops Dicotyledons*, Longman, London p. 719

Radhakrishna, T. and Jebaraj, S. 1982. Genetic variability in cowpea (*Vigna unguiculata* (L.) Walp). *Madras agric J.* 69: 216-219

Rajendran, R., Biswas, S.R., Ramachander, P.R., Satyanarayana, A., Anand, N. and Srinivasan, K.1979. Genetic improvement of cowpea (*Vigna unguiculata* (L.) Walp) for seed yield. *Agric. Res. J. Kerala* 17 (1) : 60-66

Ram, T., Ansari, M.M. and Sharma, T.V. R.S. 1994. Relative performance of cowpea genotypes in rainfed conditions in Andaman and their genetic parameter analysis for seed yield. *Indian J. of pulses Res.* 7 (1) : 72-75

Ramachandran, C., Peter, K. V. and Gopalakrishnan, P. K. 1980. Variability in selected varieties of cowpea. *Agric. Res. J. Kerala.* **18** (1) : 94-97

Ramaswamy, S. B. 1988. Host finding by moths : Sensory modalities and behaviours. *Journal of Insect Physiology* **34** : 235-249

Resmi, P.S. 1998. Genetic variability in yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Verdcourt, *M.Sc. (Ag.) Thesis.* Kerala agric. Univ., Thrissur

Russell, G. E. 1978. *Plant Breeding for Pest and Disease Resistance* Butterworth and Co., London p. 485

Salifu, A. B., Singh, S. R. and Hodgson, C. J. 1988. Mechanism of resistance in cowpea (*Vigna ugnuiculata* L. Walp.) genotype, TVX 3236, to the bean flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera : Thripidae) 2. Non preference and antibiosis. *Trop. Pest Management* **34** (2) : 185-188

Saxena, R. C. and Khan, Z. R. 1991. Genetics of insect - hostplant interactions : Concepts, old and new. In *Advances in Plant Breeding* Vol. I (Eds. A. K. Mandal, P. K. Ganguli and S. P. Banerjee). 111-120. CBS Publishers and Distributors, Delhi

*Schillinger, J. A. and Gallun, R. L. 1968. Leaf pubescence of wehat as a deterrent to the cereal leaf beetle, *Oulema melanoplus*. *Ann. Entomol. Soc. Am.* **61** : 900-903

Shakarad, M. N., Arathi, H. S., Gangappa, E. and Ramesh, S. 1995. Gene action for yield and yield attributes in cowpea (*Vigna unguiculata* (L.) Walp). *Mysore J. agric. Sci.* **29** (4) : 289-292

Sharma, P. C., Mishra, S. N., Amarjit Singh and Verma, J. S. 1988. Genetic variation and correlation in cowpea. *Ann. agric. Res.* **9** (1) : 10-105

Shepard, M., Carner, G. R., Turnipseed, S.G. 1977. Colonization and resurgence of insect pests of soybean is response to insecticides and field isolation. *Environ. Entomol.* **6** : 501-506

Singh, K. B. and Mehndiratta, P. D. 1969. Genetic variability and correlation studies in cowpea. *Indian J. Genet.* **29** : 104-109

Singh, S. R. 1978. Resistance to pests of cowpea in Nigeria. In *Pests of Grain Legumes : Ecology and Control*. Singh, S. R., van Emden, H. F. and Taylor, T. A. (Eds.). pp. 267-280, Academic Press, London

*Smith, C. M. 1989. *Plant resistance to insects : A fundamental approach.* Wiley, Chichester, U. K. pp. 286

Snelling, R. O. 1941. Resistance of plants to insect attack. *Bot. Rev.* 7 : 543-586

Sobha, P. P. 1994. Variability and heterosis in bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp). *M.Sc. (Ag.) Thesis.* Kerala agric. Univ., Thrissur

*Southwood, T. R. E. 1986. Plant surfaces and insects - an overview. pp. 1-22. In Juniper, B. and Southwood, T. R. E. (Eds.) *Insects and the plant surface* p. 360. Edward Arnold, London

Sreekumar, K. 1995. Genetic analysis of biological nitrogen fixation traits and yield cinoibebt ub ciwoea (*Vigna unguiculata* (L.) Walp.) *Ph.D. Thesis*, Kerala agric. Univ., Thrissur

Sreekumar, K., Inasi, K. A., Antony, A. and Nair, R. R. 1996. Genetic variability, heritability and correlation studies in vegetable cowpea (*Vigna unguiculata* var. *sesquipedalis*). *South Indian Hort.* : **44** (1 & 2) : 15-18

Sulochana, K. A. and Peter, K. V. 1986. Evaluation of host reaction to *Aphis craccivora* Koch. in Cowpea. *Agric. Res. J. Kerala* **24** (1) : 63-65

Tamilselvam, A. and Das, L.D.V. 1994. Correlation studies in cowpea (*Vigna unguiculata* (L.) Walp) for seed yield. *Madras agric J.* 81 (8) : 445-446

Tamo, M., Bottenberg, H, Arodokoun, D., Adeoti, R. 1990. The feasibility of classical biological control of two major cowpea insect pests. *Advances in cowpea reserch*, IITA, Ibadan, Nigeria pp.259-270

Tingey, W. M. 1981. The environmental control of insect, using plant resistance. In *CRC Handbook of pest management in agriculture* (Ed. D. Pinentel) 175-197, CRC Press, Florida

Tingey, W. M. 1986. Techniques for evaluating plant resistance to insects. In : *Insect - Plant Interactions*. J. A. Miller and T. A. Miller (Eds.) Springer- Verlag, New York pp. 251-284

*Todd, G. W., Getahun, A. and Cress, D. C. 1971. Resistance in barley to greenbug. *Schizaphis graminum*. 1. Toxicity of phenolic and flavonoid compounds and related susbstances. Annals of the Entomological Society of America **64** : 718-722

Vaid, I.K. and Singh, K.B. 1983. Genetic variability in F_3 and F_4 populations of a cross in cowpea (*Vigna sinesis* (L.)). *Madras agric. J.* 70 (5) : 281-283

Veda, O. P., Purohit, M. L. and Sood, N. K. 1975. Varietal susceptibility of arhar (*Cajanus cajan* (L.) Millsp.) to *Melanagromyza obtusa* Mall. *Exellastis atmosa* W. and *Heliothis armigera* Hb. *JNKVV Res. J.* **9** (1 & 2) : 7-9

*Webster, J. H. 1975. *Association of plant hairs and insect resistance*. An annotated bibliography. USDA-ARS, Miscellaneous Publication. United States Department of Agriculture, Agricultural Research Service 1297

*Wolley, J. N., Evans, A. M. 1979. Screening for resistance to *Maruca testulalis* (Geyer) in cowpea (*Vigna unguiculata* (L.) Walp.). *J. agric. Sci.*, Camb. **92** : 417-425

*Wright, S. 1921. Correlation and Causation. *J. Agric. Res.* ***20*** : 557-585

*Yap, T.C. 1983. Genetic studies and improvement of long bean (*Vigna unguiculata* (L.) Walp) in Malaysia. *Crop Improvement* 295-302

*Ye, Z. B. and Zhang, W. B. 1987. Inheritance studies and correlations between quantitative characters in *Vigna sesquipedalis*. *Acta Horticulturae Sinica* **14** (4) : 257-264

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* Original not seen

EVALUATION OF VEGETABLE COWPEA (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) FOR LEGUME POD BORER, *Maruca vitrata* (Fab.) RESISTANCE AND YIELD

BY

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ABSTRACT

The present study aimed at screening vegetable cowpea germplasm for legume pod borer resistance and evaluation of partially resistant cultivars thus identified for yield was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani. Data for the investigation were collected from two field experiments conducted during the period 1997-1999.

In the field screening programme for legume pod borer resistance, 51 diverse cultivars were evaluated on the basis of overall plant resistance index (Ipr) computed using a combination of flower, pod and seed damage measurements. The damage parameters employed in the computation of Ipr were number of larvae in 25 flowers, percentage pod infestation and seed damage index (Jackai, 1982). Significant differences between cultivars were observed for these damage parameters as well as the resistance index computed based on them. Differences among cultivars in the severity of pod damage assessed as number of entry / exit holes on pod samples were also significant.

The cultivar suffering least flower damage was Vs 27. The cultivars Vs 2 and 28 recorded the lowest percentage pod infestation as well as pod damage severity. Cultivar with the lowest seed damage was Vs 13. Lower Ipr values indicate higher levels of plant resistance. Consequently Vs 27 with the lowest Ipr value was identified as the most resistant among the 51 cultivars. Other cultivars on par with Vs 27 were Vs 2, Vs 7, Vs 8, Vs 10, Vs 19, Vs 28, Vs 31 and Vs 35.

Correlation analysis of different damage parameters did not suggest any relationship between flower and seed damages. Percentage pod infestation and pod damage severity showed highly significant positive correlation between them but were uncorrelated with larval count in flowers. Seed damage was found to be positively correlated with pod damage.

Despite differences in total leaf chlorophyll content among the cultivars, the correlation between total leaf chlorophyll content and plant resistance index was non-significant indicating the absence of any relationship between them. Similarly peduncle length did not show any relationship with Ipr as well as the different damage parameters. However, pod width was found to be positively correlated with Ipr, pod damage severity and percentage pod infestation. Non-glandular trichome density on pods recorded significant negative correlation with Ipr and pod damage indicating that plant resistance increases with increase in non-glandular trichome density on pods.

Fifteen top ranking cultivars with respect to legume pod borer resistance were chosen and evaluated for yield and its components in a field experiment in RBD with three replications.

Analysis of variances revealed significant difference among the varieties for eleven out of the fourteen characters studied. The cultivar Vs 14 was the top yielder of vegetable pods with Vs 24 on par with it. Highest pod length was recorded by Vs 28 and highest pod weight by Vs 2. High heritability and genetic advance were recorded for number of pods per plant, yield of vegetable pods per plant and pod weight.

Number of pods per plant had high direct effect on vegetable pod yield. Its correlation with yield was significant and positive. This suggested that number of pods per plant is a character important in selection programmes for yield in vegetable cowpea.

The cultivars Vs 14 and Vs 24 which were high yielders among the partially resistant accessions were identified as varieties suitable for cultivation in legume pod borer endemic areas.