HOST RESISTANCE IN COWPEA (*Vigna unguiculata* (L.) Walp) TO THE POD BORER *Maruca testulalis* (Geyer) (PYRALIDAE : LEPIDOPTERA)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
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DECLARATION

I hereby declare that this thesis entitled "**Host resistance in cowpea (*Vigna unguiculata* (L.) Walp) to the pod borer *Maruca testulalis* (Geyer) (Pyralidae:Lepidoptera)**" is a bonafide record for research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship of any other similar title, of any other University or Society

Vellanikkara,

1992

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CERTIFICATE

Certified that the thesis entitled "Host resistance in cowpea (*Vigna unguiculata* (L.) Walp), to the pod borer *Maruca testulalis* (Geyer) (Pyralidae:Lepidoptera)" is a record of research work done independently by Mrs.ANITHA KUMARI,V. 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

Cowpea, Vigna unguiculata (L.) Walp, one of the most important pulse crops in India, has a wide range of ecological adaptation and is grown widely in the semi-arid and sub-humid tropical areas. The cultivation of cowpea has received a set back due to the losses due to the insect pests. Losses due to pests vary from 20 to almost 100 per cent. The most important field pests of cowpea are aphids, pod borers, pod sucking bugs, foliage beetles, leaf hoppers and thrips. Of all these pests, pod borers are a major constraint in the pulse production in the country.

The legume pod borer, Maruca testulalis (Geyer) is a pyralid that occurs throughout the tropics and subtropics of Central and South America, Asia and Africa. It is reported as a major pest of cowpea, beans, mung bean, winged bean, yard long bean and groundnut. The early instars of this pod-borer infest tender parts of the stem, terminal shoots and peduncles. Later, the pest population builds up in the flowers and pods of the cowpea crop. Flowers, pods and leaves are usually webbed together and the frass is often visible on pods and shoot tips when the pest is present.

Extensive field surveys in Orissa to assess the crop loss in pigeon pea caused by pod-borers revealed that M. testulalis (Geyer) was the dominant species causing injury which varied from 8.24 to 15.91 per cent resulting in a loss of 3.69 to 8.89 per cent yield

(Patnaik *et al.*, 1986). Confinement of larvae of *M. testulalis* (Geyer) on flowers of beans caused more than 52 3 per cent damage, while on pods and leaves, it was 37.8 and 9.9 per cent respectively (Karel, 1985).

Being an internal feeder, direct insecticidal control of the pest is extremely difficult. Scheduled applications of synthetic insecticides at specified intervals are therefore recommended as a prophylactic measure throughout the cropping period against the borer pest. However, there has been growing concern about the hazards due to terminal residues in cowpea which has a large complex of insect pests that may need the use of broad spectrum insecticides. Alternative low cost insect control strategies that are effective and safe are hence needed. It is, therefore, imperative that, other control options be investigated, not necessarily as replacement of insecticides, but rather, as part of an integrated approach for managing the pest.

Inorder to develop a meaningful strategy for control of this pest, the various components of pest management are being studied with emphasis on host plant resistance. The utilisation of host plant resistance for the population management of crop pests is one of the well known approaches in crop protection research. Although complete resistance or immunity may be near to ideal, partial resistance would also be of immense value and can fit well into any integrated pest management system. Insecticidal methods of control of pests of vegetable crops have shown encouraging results even under low levels of host plant resistance. A low level of resistance may, by reducing the viability of the pests favour the activity of the natural enemies to the extent that, effective control is achieved. The resistant varieties will be much more stable at the level of the subsistence farmer, but, inorder to achieve higher yields, other control measures including insecticide application will be necessary. It was revealed by Jackai et al. (1985) that in cowpea, the dependence on insecticides can be further reduced with the development of multiple insect resistant lines.

Identification of sources of resistance by screening the germplasm of cowpea and working out the mechanism of resistance are essential steps to develop genotypes with desired levels of resistance.

The research work carried out on host plant resistance in cowpea to infestation by M. testulalis (Geyer) is still not adequate. Studies on host resistance in cowpea against M. testulalis (Geyer) have been carried out by several workers (Singh et al., 1976; Singh, 1978; Taylor, 1978; Jackai, 1981, 1982).

In the above background, the present studies have been taken up to screen the germplasm reserves consisting of cultivars/varieties of cowpea with reference to their susceptibility/resistance to infestation by M. testulalis (Geyer). The biophysical and biochemical basis of resistance to M testulalis (Geyer) is also envisaged with a view to understand the mechanism of resistance.

Review of Literature

2. REVIEW OF LITERATURE

Moderate level of host plant resistance is a vital component of the integrated pest management systems of crops. Painter (1951) defined resistance as the relative ability of a certain plant variety, due to some specific inherited qualities, to suffer less damage or infestation than other ordinary varieties under the same or comparable environments in the field. The mechanisms include non-preference, antibiosis and tolerance (Painter, 1951; 1958).

Non-preference refers to the plant characteristics that discourage its use for oviposition, food or shelter. Non-preference of crop varieties for feeding and or oviposition has been reported by several workers (Beck, 1965, Rang dang et al., 1970, Chakravarthy, 1978; Singh and Jotwani, 1980a; Jackai et al., 1981; Macfoy et al., 1983 and Jayappa et al., 1988).

Antibiosis signifies those preventive, injurious or destructive effects which the host plant exercises on the insect's normal life. Lowered fecundity, reduced growth rate, prolongation of the larval period, reduced survival, reduced larval and pupal weight, decrease in life span of adults and unfavourable female-male ratio are different types of antibiosis in crops to several pests (Painter, 1966; Jayaraj, 1967a, Panda et al., 1972; Chari et al., 1976, Karel et al., 1980; Gurumukhi et al., 1983; Messina et al., 1985).

In investigating the antibiotic effects of the resistant wild melon, Cucumis callosus (Rottle) on the fruit fly, Dacus cucurbitae coq., Chelliah et al. (1974) observed that proportionately less number of female adults emerged from the resistant than from susceptible fruits. It was also observed that the fruit fly reared on the resistant host registered low larval survival, prolonged larval period, low fecundity and longevity. The results of the study of Panda and Das (1975) revealed a higher female/male ratio of the fruit and shoot borer, Leucinodes orbonalis Guen. when reared on susceptible brinjal accessions.

Chakravarthy (1978) reported that the antibiotic mechanism of resistance in field bean cultivars to the pod borer, Adisura atkinsoni Moore was manifested as decreased larval survival, reduced larval and pupal weights, prolonged larval duration, and altered sex ratio. Similar observations were recorded by Lall and Sukhani (1982) in the case of Chilo partellus (S.) reared on sorghum varieties.

Ofuya et al. (1986) stated that in the cowpea varieties TVU 3709 and BPL-3-1 resistant to the black cowpea moth, Cydia ptychora (Meyrick) larval mortality was recorded to be very high. In these varieties, the adult females had the lowest fecundity, fertility and life span. In another resistant variety Vita-5, the larvae were slower in developing to adults than on other varieties. Antibiosis was manifested as extended immature developmental period and decreased survival in cowpea (*V. unguiculata* (L.) Walp) genotype TVX 3236, to the bean flower thrips, *Megalurothrips sjostedti* (Trybom.) (Salifu *et al.*, 1988). Hammond and Cooper (1989) stated that in the soybean (*Glycine max* (L.) Merr.) germplasm lines resistant to Mexican bean beetle *Epilachna varivestis* Mulsant., the mortality rates of larvae were higher compared to that in the susceptible lines.

Tolerance specifies the host plant's ability to sustain a pest population by rapidly repairing or overcoming injury and maintaining its growth and yield. In view of the non-involvement of the biophysical and biochemical attributes of the plant variety, it is not proper to classify tolerance under resistance (Beck, 1965, 1974). Beck (1965) classified the tolerance mechanism into pseudoresistance to include phenological evasion, induced resistance and transitory and other incidental resistance.

Comprehensive reviews on the various aspects of insect resistance in crop plants have been made by several workers (Painter, 1951, 1958, Nath Prem, 1964; Jayaraj, 1976; Maxwell, 1977; Panda, 1979; Pathak and Dale, 1983; Khaemba, 1985; Saxena, 1985; Singh, 1987). In investigating the mechanism of resistance in cowpea to the southern green stink bug, *Nezara viridula* (L.), Schalk *et al.* (1986) reported that tolerance was the mechanism of resistance exhibited by the promising lines.

2.1. Resistance in cowpea to insect pests

The existence of resistance to the curculio Chalcodermus aeneus (Boh.) in cowpea was reported by Cuthbert and Chambliss (1972). The tolerant variety of cowpea to Empoasca kerri Pruthi and Plusia nigrisigna (Wlk.) were identified by Ram and Singh (1973).

After screening 2800 cowpea cultivars at International Institute of Tropical Agriculture, Ibadan - Nigeria, two cowpea cultivars (TVu 946 and TVu 4557) were identified as resistant to the legume pod border, M. testulalis (Geyer) (Singh, 1978). Bindra and Sagar (1976) found out resistant cowpea variety to the spiny pod borer, Etiella zinckenella Teit.

Perrin (1978) reported that there were several varieties of cowpea in the germplasm collection at the IITA with promising levels of resistance to the cowpea black moth C. ptychora (Meyr.). Two closely related cultivars of V. unguiculata (L.) Walp, TVu 946 and TVu 2994 also showed some resistance to C. ptychora (Meyr.) (Ezueh, 1981). Several of the 26 selected cowpea cultivars had good levels of resistance to the cowpea black moth C. ptychora (Meyr.) according to the reports by Ezueh and Taylor (1981). Nilakhe and Chalfant (1982) screened twenty cowpea cultivars for resistance to nine different insect pests in field planting. Cultivars differed significantly in the degree of susceptibility to aphids, Aphis craccivora Koch, the plant bug Lygus lineolaris (P de B.), the velvet bean caterpillar Anticarsia gammatalis Hubner, the southern green stink bug N. viridula Schalk and the cowpea curculio C. aeneus (Boh.). He concluded that the chances of a cultivar resistant to several of these insect pests were rare.

Jackai (1982) developed a method for screening resistance of cowpea to the legume pod borer, M. testulalis (Geyer). Of all the test cultivars, TVu 946 was the most resistant cowpea cultivar in every category of assessment.

Methodology for screening cowpea types for resistance to M. testulalis (Geyer) was evolved by artificially infesting plants with eggs in the pre-flowering period (Dabrowski et al., 1983). Green house investigations by Macfoy et al. (1983) for resistance to M. testulalis (Geyer) indicated TVU 946 to be the most resistant both in the flowering and pre-flowering stages followed by Ife Brown and Vita-1. Results of investigation by Singh and Jackai (1983) supported the above finding where the existence of cowpea resistance to the legume pod borer for TVU 946 were confirmed.

When 438 varieties of cowpea from all over the world were grown in field plot tests in Uttar Pradesh, India, there was a wide range of tolerance of the major insect pests. The pests involved were E. kerri Pruthi, P. nigrisigna (Wlk.), Spodoptera litura (F.), Chrotogonus trachypterus Blanchard and Attractomorpha crenulata F. The Indian varieties IL 118, IL 138 and IL 148 were highly tolerant to the pest complex (Ram, Purohit and Path, 1984).

Khaemba (1985) evaluated about four thousand cultivars of V. unguiculata (L.) Walp from around the world for finding out the sources of resistance to the pod sucking bugs Riptortus dentipes (Fabricius) and Anoplocnemis curvipes (Fabricius). He revealed that out of these, 33 cultivars were moderately resistant to the coreids and were selected for further field tests. Of these, eight cultvars exhibited reasonably high levels of resistance. Preliminary screening for resistance of some local and imported plant material for resistance to the major insect pests including M. testulalis (Geyer) was carried out by Ngugi et al. (1985).

While evaluating the host resistance in cowpea to the cowpea aphid, A. craccivora Koch., out of the 83 lines tested under field conditions, 9 lines were selected for further pot culture experiments. Based on the study, TVU 889 was recommended as a source of resistance for use in breeding programme (Sulochana et al., 1986).

Jayappa and Lingappa (1988) screened ten cultivars of cowpea V. unguiculata (L.) Walp for resistance to the cowpea aphid, A. craccivora Koch. The resistant variety Mandya local, P-192, MS-370, P-1475 and TVU 2740 were least preferred by migratory aphids. They exhibited antibiosis, as evidenced by increased aphid mortality, reduced progeny, reduced survival period and reduced weight of aphids.

2.2. Effect of different biophysical factors on pest distribution

2.2.A. Pod wall thickness

The incorporation of pod wall resistance into commercial varieties of cowpea would lessen the two most objectionable results of borer pest infestation - seed injury and larval contamination.

It was reported that the hardness of fruit skin and flesh due to compact seed arrangement hindered the entry of shoot and fruit borer larvae, L. orbonalis Guen. in resistant varieties of brinjal (Srinivasan and Basheer, 1961; Krishnaiah and Vijay, 1975 and Lal et al., 1976).

Chalfant et al., 1972 and Cuthbert and Davis, 1972 reported a negative correlation between successful pod wall penetration by the curculio C. aeneus (Boh.) and pod wall thickness in cowpea. However, in cowpea, it was unable to find an association between pod wall thickness and resistance to the curculio (Ennis and Chambliss, 1976). In Lab lab niger (L.) cultivars, pod wall thickness did not form a physical barrier to the entry of the larvae of the pod borer A. atkinsoni Moore (Chakravarthy, 1978). Ezeuh, 1981 suggested that in the cultivars of V. unguiculata, pod wall thickness was not related to resistance to the cowpea moth, C. ptychora (Meyrick). Chiang and Singh (1988) found out that the pod wall of Vigna vexillata which was proved to be highly resistant to the pod sucking bug Clavigralla tomentosicollis (Stal.) was not tougher than that of the succeptible V unguiculata (L.) Walp.

Khaemba (1985) revealed that in cowpea cultivars, pod wall thickness played an important role in contributing to the resistance of the cultivars to pod sucking bugs, R. dentipes (Fabricius) and A. curvipes (Fabricius).

2.2 B. Length of flower stalk

Khaemba (1985) identified the peduncle length to be a factor determining the intensity of damage in cowpea V. unguiculata (L.) Walp. The cultivars with short peduncle were more resistant to the pod sucking bugs, R. dentipes (Fabricius) and A. curvipes (Fabricius) than those with long peduncles. Cowpea lines having long peduncles held upright over the plant canopy holding the pods away from each other appeared to suffer less damage by the legume pod borer, M. testulalis (Geyer) (IITA, 1974, 1975; Singh, 1978).

2.2.C. Configuration of calyx

Roe Singh (1980) concluded antibiosis to be the cause for a lower level of thrips, M. sjostedti (Trybom.) larvae in cowpea. He observed that the parenchyma cells of the calyx were closely packed, thus preventing the larvae from piercing into the flowers. Panda et al. (1971) and Chelliah and Srinivasan (1983) attributed the tightness of the calyx to be the cause for hindering initial entry of the larvae of L. orbonalis Guen. into brinjal fruits.

2.2.D. Pubescence

Pubescence is one of the most important physical character associated with resistance. It is a complex character involving several factors like the distribution of hairs on stems, leaves or petiole, the length of the hairs, the density of hair cover, disposition of hairs and the type of hairs (Verma and Afsal, 1940).

Parnel et al. (1949) reported that there was a strong correlation between cotton hairiness and resistance to the ovipositional preference of the leaf hopper. According to him, cotton varieties resistant to the leaf hoppers were all hairy. Similar were the reports by Balasubramaniayam and Iyengar (1950) suggesting all varieties of cotton resistant to the leaf hoppers, being hairy and all hairy varieties to be not resistant to the hoppers.

In cotton varieties, smooth leaf determines the preference for oviposition on lepidopteran pests (Lukefehr et al., 1965). Ringland and Everson (1968) through the genetic analysis revealed that resistance of wheat variety to cereal leaf beetle Oulema melanopus (L.) due to pubescent characters was quantitatively inherited and that, a high correlation existed between larval weight and density of pubescence on the substrate. According to Schillinger and Gallun (1968) gravid females of O. melanopus (L.) showed non-preference for oviposition on densely haired leaves of wheat. The number of eggs laid were reduced by greater density of pubescence. Sambandam et al. (1969) reported that the aphid Aphis gossypii Glover did not settle in Solanum mamosum L. as the plants were densely pubescent and the hairs were long.

Brar and Sandhu (1975) reported groundnut varieties with bunch or semi-spreading growth habit to be susceptible to A. cracci-vora Koch. Smith et al. (1975) stated that the pubescent variety of cotton impeded the movement of the larvae of pink boll worm, Pectinophora gossypiella (Saund.). In certain wild potato species, the presence of glandular hairs provided resistance to the green plant aphid Myzus persicae (Sulz.) and the potato aphid Macrosiphum euphorbiae (Thos.) (Cubson, 1976).

Kowaleski and Robinson (1977) screened the resistance of nineteen species of Cucumis and found the resistant species to have atleast twice or thrice number of hairs on the undersurface of leaves than the susceptible varieties. In the case of pearl millet, Pennisetum americanum L. the glabrous varieties were found to have fewer eggs of corn ear worm Heliothis zea (Boddie) on the foliage than the pubescent foliage (Leuck et al., 1977).

Quiros et al. (1977), with the field evaluations revealed an increase in hair density in tomato plants to restrict the feeding activity of potato aphid M. persicae (Sulz.).

In field bean Lab lab niger (L.), cultivars with glabrous pods were resistant to the attack of the pod borer A. atkinsoni Moore

(Chakravarthy, 1978). Beans with pubescent pods were seen to be susceptible to the pod borer infestation. Omran and Elkhidir (1978) studied the preference of leaf hair sites in cotton varieties for egg laying by the cotton white fly Bemisia tabaci (Gennadius). It was found that B. tabaci (Gennadius) fixed the eggs at the bases of leaf hairs of cotton. The rejection of cotton varieties bearing non hairy leaves were presumed to be due to the lack of suitable egg laying sites. But Niles (1980) was of the opinion that, there was no indication that glabrousness would confer resistance of B. tabaci (Gennadius). Bulter and Henneberry (1984) reported that the pubescent variety of cotton were highly preferred by B. tabaci (Gennadius).

Chiang et al. (1988) in studying the influence of pod hairs in V. vexillata to resistance to the pod sucking bug, C. tomentosicollis (Stal) found out that the trichomes on the pod of V. vexillata partly accounted for its resistance to the pest. In order to understand the mechanism of resistance to agromyzid flies in mung bean accessions, three resistant and two susceptible varieties of mung bean were examined. It was observed that the trichome density was high on leaves and stem of highly resistant accessions of mung bean (Talekar et al., 1988).

2.3. Biochemical factors of host plants

The nutritive value of the host plants to insects feeding on them appears to play an important role in determining the susceptibility to the insect attack.

Hsiao (1969, 1972) and Thornsteinson (1969) stated that the chemical composition of plants is of fundamental significance in the acceptance or rejection of the host plants either for food or oviposition by insects.

2.3.A. Sugars

It was reported by several workers that the higher sugar content in plants is related to the level of susceptibility to pests. Sugars acted as feeding stimulants and the larvae fed most intensively on plant parts containing the highest concentration of sugars.

High concentration of reducing and total sugars in the silks of corn varieties were found responsible for the susceptibility of the varieties to the corn ear worm, Ostrinia nubilalis (Hb.) (Knap, 1960).

In studying the biochemical mechanism of resistance in sorghum shoot fly Atherigona varia soccata (Round), it was revealed by Singh et al. (1980) that the concentration of reducing and total sugars were higher in the susceptible varieties compared to the resistant ones. Ezueh (1981) stated that the wild and semi-wild cowpea varieties resistant to the cowpea moth C. ptychora (Meyrick) were lower in both nitrogen and carbohydrate contents than the genetically improved ones He concluded that these varieties might have been nutritionally inadequate for the larvae.

Macfoy et al. (1982) in investigating the biochemical mechanism of resistance in cowpea cultivars to the legume pod borer, M. testulalis (Geyer) revealed that the levels of both total sugars and total amino acids were quantitatively lower in the resistant than in the susceptible varieties.

Contrary to the above trends, some scientists have reported an indirect correlation of sugar concentration in plants and susceptibility to insect pests. Brett et al., 1965 stated that the concentration of D-glucose above one per cent in squash varieties rendered them resistant to the pickle worm Diaphana nitidalis (Stoll.). Higher concentration of sugars was found to be responsible for the tolerance mechanism exhibited by a potato variety seqoia tolerant to the leaf hopper Empoasca fabae (Harr.) (Hebbs et al., 1964).

Jayaraj (1967a) while screening the castor varieties resistant to the leaf hopper Empoasca flavescens (F.), detected excessive accumulation of carbohydrate and lower amino acids. It was reported by Maltais and Auclair (1967) that pea varieties resistant to Acyrthosiphon pisum (H.) contained higher concentration of sugars. In studying the influence of biochemical components on the resistance in blackgram cultivars to insect pests and yellow mosaic virus, it was found that the leaves of resistant cultivars had higher contents of reducing and non-reducing sugars (Chhabra *et al.*, 1981a).

2.3.B. Amino acids

Auclair and Maltais (1950) identified that the pea varieties susceptible to *A. pisum* (H.) generally contained a higher concentration of amino acids than the resistant varieties. According to Beck and Hance (1958) the amino acids and sugars show additive effects on maintenance of feeding. Auclair *et al.* (1957) pointed out the lower amino acid concentration in the pea plant sap to be an important component responsible for antibiosis in the pea varieties to infestation by the pea aphid *A. pisum* (H.).

The additive effects of amino acids and sugars was reported by Thornteinson (1960) in the case of several grass hoppers. Mehta (1971) could not detect any additive effect for sugars and amino acids in eliciting improved feeding responses from the boll worm *Earias fabia* Stoll. infesting cotton.

Knap (1960) revealed that the silks of certain corn lines resistant to the ear worm had lower concentration of amino acids than those of susceptible varieties. Auclair in 1962 and 1963 reported that the pea varieties susceptible to *A. pisum* (H.) had higher concentration of homoserine, glutamine and aspargine than resistant varieties.

Banepal and Hall (1967) observed that in cauliflower free amino acids and total soluble nitrogen were relatively higher in varieties susceptible to the cabbage looper Trichoplusia ni H. and rape white butterfly Pieris rapae (L.) than in resistant varieties. The castor varieties resistant to the leaf hopper E. flavescens (F.) contained lesser quantities of total nitrogen, free amino acids and peptides (Jayaraj, 1967b)

Boyd (1970) postulated that deficiency of amino acids in plants curtailed viability of insects which feed on such plants. Thirumurthi (1970) stated that the sorghum varieties susceptible to the shoot fly A. V. soccata Round., contained more number of essential amino acids in free state at higher concentration than in resistant varieties.

In contrast to the general trend, Maltais (1959) did not find any correlation between amino acid concentration and the incidence of pea aphid, A. pisum (H.). Van Emden and Bash Ford (1971), found that high concentration of some amino acids could adversely affect the growth and development of aphids on plants.

Natarajan (1971) attributed the lower quantities of total nitrogen, amino nitrogen, amino acids and crude fibre in brinjal varieties in conferring resistance to the epilachna beetle, Epilachna vigintioctopunctata (Fabricius). Venkatanarayanan (1971) observed that higher contents of total nitrogen and free amino acids and lower levels of total carbohydrate with a narrow carbohydrate - nitrogen ratio favoured the development of leaf hoppers in paddy.

In the varieties of C. callosus (Rottl.) resistant to the fruit fly D. cucurbitae Coq., lower quantities of essential amino acids, sugars, organic acids and minerals were detected (Sambandam and Chelliah, 1972). Srivastava and Auclair (1974, 1975) suggested that certain amino acids either alone or in combination act synergistically with sucrose as phagostimulant to pea aphid, A. pisum (H.).

The biochemical analysis of cowpea cultivars revealed a higher concentration of sugars, amino acids and proteins in the varieties susceptible to M. testulalis (Geyer) and lower concentration in the resistant varieties (Macfoy et al., 1982). Basavangoud et al. (1980) observed that the safflower varieties resistant to the aphid Dactynotus compositae T. had lower levels of amino acids. Rawat and Shaw (1983) found positive correlation between the total amino acid content in pea varieties and infestation by Caliothrips indicus (B.).

2.3.C. Nitrogen and Protein

In the cabbage aphid, Brevicoryne brassicae (L.) it was observed that the rate of reproduction was positively correlated with the nitrogen and protein content of the host plant (Evans, 1938). Van Emden (1966) reported that aphids were highly sensitive to the levels of nitrogen in the plant and that, they responded negatively to levels of potassium even in the presence of high nitrogen. Sharma and Chatterji (1971) found that the mean percent of nitrogen, phosphorus and potassium were significantly higher in the varieties of sorghum susceptible to Chilo zonellus (Swinh.). The level of nitrogen applied in the soil has a tremendous effect on the infestation of rice stem borers (Saroja and Raju, 1981).

In assessing the biochemical basis of resistance in sorghum to shoot fly A. V. soccata Round., Singh and Jotwani (1980) attributed the susceptibility of varieties to the higher per cent of nitrogen in their leaves and leaf sheath.

Macfoy et al. (1982) found out that the cowpea varieties resistant to the pod borer M. testulalis (Geyer) to have the lowest quantity of both total nitrogen and protein. Isahaque and Chaudhuri (1984) observed a low protein and sugar content in genotypes of egg plant resistant to the fruit and shoot borer L. orbonalis Guen.

Contrary to the above,, it was reported by Harrks (1966) that the seedlings of peach, apple, cherry and pear which were deficient in nitrogen showed susceptibility to the red spider mite, Tetranychus urticae Koch.

Materials and Methods

3. MATERIALS AND METHODS

The field trial for screening hundred cowpea varieties for resistance to the pod borer, M. testulalis (Geyer) was conducted in the Instructional Farm attached to the College of Horticulture, Vellanikkara, during the monsoon season during June-September, 1990. Based on the results obtained from the above study, the cowpea accessions were categorised into susceptible or resistant groups These were further tested in the laboratory during December-February, 1991 to determine the mechanism of resistance using selected accessions drawn from each category of plants.

The details of the accessions of cowpea (V. unguiculata (L.) Walp) screened for field resistance during the monsoon season are furnished in Table 1.

Rearing of M. testulalis Geyer in the laboratory

A good stock culture of M. testulalis (Geyer) required for the experiments was maintained in cages (45 x 45 x 90 cm). The cages had wooden frames fitted with polynet on all the sides and top with a door on one side. The base of the cage was provided with wooden planks.

The susceptible cowpea variety Pusa Komal was used for the mass rearing of the insect in the laboratory. The larvae of M. testulalis (Geyer)

Table 1. Details of the cowpea varieties screened in the field for resistance to the pod borer, *M. testulalis* (Geyer)

Serial Number	NBPGR No.	Source	Plant habit
V1	230	Kollam	Trailing
V2	75	Palakkadu	"
V3	310	Tamil Nadu	"
V4	836	Ernakulam	"
V5	748	Olavakkode	Semi trailing
V6	759	Palakadu	Trailing
V7	961	Thirunelveli	"
V8	665	Malappuram	"
V9	252	Tamil Nadu	"
V10	1539	Tamil Nadu	"
V11	478	Payannoor	"
V12	125	Kerala	"
V13	228	Tamil Nadu	"
V14	539	Cannannoore	"
V15	221	Tamil Nadu	"
V16	2	Maharashtra	"
V17	825	Kalady	"
V18	1479	Uttar Pradesh	"
V19	17	Kerala	"
V20	998	Thirunelveli	"
V21	46	Trichur	Semi Trailing
V22	854	Kalady	Trailing
V23	144	Kerala	"
V24	1502	Uttar Pradesh	"
V25	403	Punalur	Bushy
V26	9	Maharashtra	Trailing
V27	236	Tamil Nadu	Bushy
V28	217	Kerala	Trailing
V29	113	Kerala	"

Table 1. Continued

1	2	3	4
V30	Mannuthy local	Mannuthy	Trailing
V31	18	Maharashtra	"
V32	143	Kerala	"
V33	323	Tamil Nadu	"
V34	916	Kothamangalam	"
V35	770	Palakkadu	"
V36	168	Maharashtra	"
V37	1529	Bihar	Bushy
V38	1518	Maharashtra	Trailing
V39	1481	Pauri	"
V40	687	Malapuram	"
V41	644	Calicut	"
V42	116	Kerala	"
V43	220	Tamil Nadu	"
V44	180	Kerala	"
V45	269	Tamil Nadu	"
V46	1073	Madurai	"
V47	1097	Kerala	"
V48	1485	Nainital	"
V49	425	Kottayam	Bushy
V50	5	Maharashtra	"
V51	158	Tamil Nadu	Trailing
V52	831	Ernakulam	"
V53	705	Palakkadu	"
V54	GC-82-7	Vellayani	"
V55	DPLC-210	Vellayani	Bushy
V56	K38956	Vellayani	Trailing
V57	516	Ernakulam	"
V58	603	Wayanadu	"
V59	736	Palakkad	"

Table 1. Continued

1	2	3	4
V60	275	Wayanadu	Bushy
V61	722	Palakkadu	Trailing
V62	222	Tamil Nadu	"
V63	677	Malappuram	"
V64	572	Wayanadu	Trailing
V65	717	Palakkadu	"
V66	211	Kerala	"
V67	270	Tamil Nadu	"
V68	760	Palakkadu	"
V69	13	Kerala	"
V70	239	Tamil Nadu	"
V71	776	Palakkadu	"
V72	253	Tamil Nadu	"
V73	16	Maharashtra	"
V74	280	Tamil Nadu	"
V75	416	Kollam	"
V76	66	Kerala	Bushy
V77	38	Kerala	Semi bushy
V78	877	Ernakulam	Bushy
V79	849	Kerala	"
V80	181	Kerala	"
V81	1466	Karnataka	"
V82	1524	Maharashtra	"
V83	176	Kerala	Trailing
V84	1527	Andra Pradesh	"
V85	1534	Bihar	"
V86	679	Malappuram	"
V87	1480	Uttar Pradesh	"
V88	420	Ernakulam	"
V89	Kanakamony	Pattambi	"

Table 1. Continued

1	2	3	4
V90	11	Maharashtra	"
V91	248	Tamil Nadu	Bushy
V92	129	Kerala	"
V93	160	Kerala	Semi trailing
V94	951	Ettumanoor	"
V95	703	Trichur	"
V96	678	Malappuram	Trailing
V97	1501	Uttar Pradesh	Bushy
V98	Kuruthola	Trichur	Semi bushy
V99	15	Maharashtra	Bushy
V100	Pusa Komal	Trichur	"

taken from the infested cowpea flowers and pods formed the nucleus of the lab culture. Fifth instar larvae ready for pupation, identified by their brownish green body with characteristic black spots through out the body were transferred for pupation to petridishes in which circular paper discs were provided. The petridishes with the pupae were kept inside a cage containing a potted plant of Pusa Komal in the flowering stage.

The adults started emerging from the sixth day after pupation. Most of the adults emerged on the eighth day after pupation. Cotton swabs soaked in honey were placed on the cowpea plants to provide artificial food for the adults. The adults mated freely inside the cage. The gravid females started laying eggs on the flowers, flower buds and young pods. The eggs hatched within 2-3 days and the first instar larvae started feeding at the oviposition sites. These first instar larvae served as the material for taking up the various experiments. A fairly good proportion of the larvae were allowed to feed and grow on the caged plants. After about ten days, the fifth instar larvae ready to pupate were collected and placed in petridishes. The pupae were placed in rearing cages for the emergence of adults as done before. The female adults laid eggs on the inflorescence of the potted plant placed in the cage. Thus a continuous good stock culture of the insect, M. testulalis (Geyer) was maintained in the lab.

Plate: Field screening of cowpea lines for resistance

3.1. Field screening of cowpea lines for resistance to *M. testulalis* (Geyer)

Field evaluation of hundred cowpea varieties was carried out by raising double rows of cowpea plants giving a spacing of 45 x 15 cm. There were ten plants in each row. The experiment was replicated twice. Each replication had twenty plants for all the different varieties (Plate I). Farm yard manure was applied and incorporated uniformly at the rate of 15 t/ha, by ploughing and taking of ridges. Urea, superphosphate and muriate of potash were applied @ 20:30:10 kg/ha respectively. Fifteen days after sowing, a top dressing with urea to supply nitrogen @ 15 kg/ha was also given. The susceptible check Pusa Komal was grown as a border around the plot. At the flowering stage, the population level of *M. testulalis* (Geyer) was low and hence laboratory reared first and second instar larvae were released on the susceptible check. Observations on the pod borer incidence were recorded at weekly intervals upto two months after flowering. Five plants were selected at random from each line and the pod borer incidence on flowers and pods were recorded The percentage of damage was calculated based on the ratio of the infested pods to the total number of pods.

Based on the attack levels, the cowpea lines were categorised into four classes namely resistant, moderately resistant, moderately susceptible and highly susceptible.

Mean per cent pod damage	Groups
0-5 % damage	Resistant
5-10 % damage	Moderately resistant
10-15 % damage	Moderately susceptible
>15 % damage	Highly susceptible

3.1.A. Laboratory studies

For detailed laboratory studies on the mechanisms involved in resistance, five accessions were selected from each group based on the field trial and they were subjected to the following studies.

3.1.A.I. Raising potted plants of different accessions of cowpea

Pots of size 25 x 25 cm were used for raising plants of different accessions required for the experiments. Potting mixture was prepared by mixing dry powdered cattle manure, soil and sand in equal proportion. There were fifteen plants for each of the accessions.

For ensuring a continuous availability of pods for the various experiments, each variety was sown in a phased manner at fortnightly intervals The plants were watered regularly and well maintained.

3.1 A.I.a. Assessment of the flower and pod damage on caged cowpea accessions

Cages similar to those used for the laboratory rearing of M. testulalis (Geyer) were used for this experiment. A single potted plant of each accession in the flowering stage was placed inside the cage. Ten first instar larvae, drawn from the laboratory culture were released on the plant using fine camel hair brush. This trial was replicated thrice. A count of total number of flowers and the number of flowers infested were recorded. Similar observations were made when the plants were in the maximum podded stage too. The total number of pods and the number of pods infested were also recorded. The percentage of flower and pod infestations were calculated and subjected to analysis of variance.

3.1.B. Influence of different cowpea accessions on the biology of M. testulalis (Geyer)

3.1.B.I Evaluation of the larval survival on the flowers and pods

To study the larval survival on the flowers, petridishes (9.5 cm diameter) were taken and both the plates were covered with moist tissue paper. Flower buds and flowers collected from a single accession were kept in the petridishes at the rate of five buds/flowers per dish. These flowers were inoculated with five first instar larvae of M. testulalis (Geyer). The flower stalks were wrapped with wet cotton swabs to prevent rapid withering. The petridishes were kept undisturbed for 24 hours. On the next day, the number of flowers infested by the pod borer larvae were taken to count and the per cent suvival of the larvae on the flowers was calculated. The same procedure was carried out for all the treatments and each treatment was replicated thrice.

To evaluate the larval survival on the pods of the different accessions, ten pods from each accession were taken in a glass trough lined with moist tissue paper. Ten first instar larvae of M. testulalis (Geyer) were released in each of the glass troughs The troughs were covered with moistened muslin cloth. Each treatment was replicated thrice. The number of larvae which pupated in the glass troughs out of the total number released were recorded from the 8th day upto the 12th day after the release of the larvae. The percentage of larvae pupated was taken as an indicator of the larval survival. The data were statistically analysed.

3.1.B.II. Influence of accessions on the development duration

The number of days taken by the larvae from the date of its emergence to reach the adult stage was recorded and expressed as development duration. Freshly emerged larvae were carefully transferred to the pods of different accessions using a fine brush There were ten larvae for each of the accessions. Care was taken for prompt changing of pods. The mean duration of development was worked out for each accession.

3 1.B.III. Influence on the adult emergence

As a continuation of the former experiment to determine the development duration, the adult emergence trends were also recorded. Adult emergence per cent was then calculated as the per cent of larvae that emerged out of the total released on the accessions. The experiment was repeated for all the accessions and each treatment was replicated thrice.

3.1.B.IV. Influence of accessions on the sex ratio

Twenty numbers of first instar larvae of M. testulalis (Geyer) were reared on the pods of different accessions in glass troughs until pupation. Pupae were collected and transferred to glass jars covered with muslin cloth for the adult emergence. Adults were sexed out and the number of female and male moths were recorded There were three replications. From this, the proportion of female moths was calculated as a percentage of the number of female moths to the total number of adults. The observations were statistically analysed.

3.1.B.V. Fecundity of F_1 females reared on the pods

A single pair of freshly emerged moths collected from the trial for determining the proportion of females was immediately transferred into glass jars provided with respective inflorescence. Besides they were fed with 10 per cent sucrose solution in cotton wool which was replaced daily. The inflorescences were collected daily and fresh flowers introduced. Five glass jars were maintained as a replication. Observations were made daily for the presence of the eggs on flowers and flower buds for seven days (mating period two days and oviposition period five days). The same procedure was adopted for all the varieties under study. The mean number of eggs laid by a single female moth was worked out and the data were statistically analysed.

3.2. Influence of the biophysical components of the accessions on resistance to the pod borer *M. testulalis* (Geyer)

3.2.A. Thickness of pod cover - Pod wall thickness of the various varieties under consideration was measured by using a screw guage. Each treatment was replicated five times and the mean thickness was calculated.

3.2.B. Length of flower stalks - Average length of the flower stalks were measured for all the accessions. Each treatment was replicated five times.

3.2.C. Configuration of calyx - The calyx of the flowers was examined and the accessions were categorised into different groups as follows:

Free - the sepals are completely free.

Partially free - major portion of the sepals free, the basal portion tight.

Semi tight - Major portion of the sepals tight, only the tip free.

Tight - Sepals tightly attached to the flower.

3 2.C.i. Disposition of corolla - Based on the nature of the corolla, the accessions were grouped into two classes.

Loose - Petals are loosely arranged in the flower

Compact - Petals are tightly arranged in the flower

3.2.C.ii. Nature of seed testa

Based on the thickness and colour of the seed testa, the accessions were categorised. According to the thickness of the seed testa, they were classified into 'thick' and 'thin' groups. Taking the colour of the testa into consideration, they were grouped into green, cream, black and purple.

3.2.C.iii. Disposition of seeds in pods

The arrangement of seeds in the pods was examined in each accession and they were classified into the different groups.

1) Loose - the seeds were arranged with sufficient space between them

2) Moderately close - which had the seeds arranged with very little space between them

3) Very close - in which the seeds were packed very closely

3.2.D. Pubescence of the pods

Pubescent or glabrous nature of the pods was recorded with an intention to know whether it had any influence on the level of pod borer incidence. The counts of trichomes on the pod surface was made from an area of 25 mm^2 using a microscope, after placing a glass slide with markings of 5 mm x 5 mm over the excised pod. Counts from two areas on a pod were taken and the average was worked out. The trial was replicated thrice for each treatment. Based on the counts obtained, the accessions were classified into four.

Those without any trichomes within the specified area were grouped under Glabrous, those with trichome counts falling in the range of 1-10 under Sparsely pubescent, accessions with number of trichomes coming in between 10 and 20 under Pubescent, and under the Densely pubescent category, those accessions which gave a trichome count exceeding 20 were included.

3.3. Biochemical components

Biochemical analysis of the accessions was done for detecting total sugars, total N, crude protein and amino acid contents. The pods were over dried for forty eight hours and the seeds were ground to a fine powder. The methodology for the detection of different components were different.

3.3.A. Assay of the pods for total sugars
(Somogyi's alkaline copper method)

Two grams of the dry sample was transferred to a hundred millilitre volumetric flask. About ten millilitres of dilute hydrochloric acid was then added and the mixture was kept at room temperature for twenty four hours.

The sample was neutralized with 1N sodium hydroxide using phenolphthalein as the indicator and the volume was made up with distilled water and filtered. Five millilitres each of Fehlings Solution A and Fehlings Solution B were pipetted out into a 250 ml conical flask and fifty millilitres of distilled water was added. The contents were boiled and while boiling, the sample extract taken in a burette was titrated against Fehlings solution till the blue colour disappeared. Then 0.5 millilitres of methylene blue indicator was added and boiled. While boiling, titration was continued till the brick red colour was obtained. From the titre value, the per cent of sugar content was calculated. Each experiment was replicated thrice.

3.3.B. Estimation of amino acids
(Ninhydrin method introduced by Moore and Stein (1948)

One millilitre of the plant sample was pipetted out into a test tube and it was neutralised using methyl red as the indicator. 0.5 millilitre of ninhydrin reagent was added to the test tube and the contents were mixed thoroughly. A glass marble was placed on the top of each tube and the contents of the tubes were heated in a boiling water bath for twenty minutes. Five millilitres of the diluent solution was added to the mixture while it was still on the water bath. Blanks with one millilitre of distilled water alone were maintained. The tubes were removed from the water bath and cooled under running tap water. The contents were mixed thoroughly and the purple colour formed was stable. The absorbance of the solution was measured at 570 nm in a colorimeter. The amount of amino acids present was calculated using a standard curve. Each treatment was replicated thrice.

3.3.C. Determination of total N and crude protein (Microkjeldhal's digestion and distillation method)

From the dried and powdered plant sample, 0.1 gram was weighed and transferred into a digestion tube. Two grams of catalyst mixture was added through the sides of the tube. The tubes were heated gently until frothing was ceased. Boiling was continued till the solution became clear. It was allowed to cool and ten millilitres of distilled water was added to dissolve the soluble material. It was cooled again and the contents were transferred to a 100 ml volumetric flask and the volume was made up.

Twenty five millilitres of boric acid was taken in a 100 ml conical flask and two drops of methyl red - methylene blue mixed indicator was added along with two drops of bromocresol green indicator. The flask was placed below the condenser of the microkjeldhal distillation set. Pipetted out ten millilitres of the aliquot to the distillation tube. Added five millilitre of 40 per cent sodium hydroxide and all the connections were immediately closed. The distillation flask was heated to generate steam. Distilliation was carried out for about 5-10 minutes. Then the flask was removed and titrated with 0.01 N sulphuric acid till the green colour changed to purple. From the titre value, the percent of total nitrogen in the seeds was calculated. The same procedure was repeated for all the treatments and each treatment was replicated thrice.

Results

4. RESULTS

Field trial - Monsoon Crop

4.1. Screening of cowpea lines for resistance to M. testulalis (Geyer)

4.1 a. Flowers

The spread of the pod borer larvae was very low during the flowering stage of the crop. In order to ensure the build up of the pest, a good stock culture of the larvae reared in the laboratory on their initial instars (I and II) were released on the susceptible crop - Pusa Komal - which was raised as a border crop. Observations recorded on the third day with reference to the survival potential of the pest on the different accessions indicated drastic differences (Table 2). The flowers of fifty five varieties were heavily infested by the larvae. The mean percent of infestation in these were between 15.6 and 45. These were categorised under the highly susceptible group. A moderate susceptibility was found in 28 accessions where, the infestation percentage was between 11 and 14.86. Seventeen of the accessions had infestation ranging from 5.1 to 10 per cent, and these could be grouped as moderately resistant. As there were no accessions with percentage damage less than 5, none could be categorised under the resistant category.

4.1.b. Pods

Observations on the extent of damage by the borer on the pods were very identical with that of the flower damage of the

Table 2. Classification of the cowpea accessions screened for flower infestation by *M. testulalis* (Geyer)

Rating	Accessions					
1. Resistant (less than 5 per cent damage)	Sl. No.	Nil	Sl. No.	Nil	Sl. No.	Nil
2. Moderately resistant (5-10 per cent damage)	1.	V24 (5.10)	7.	V58 (10.00)	13.	V87 (8.42)
	2.	V30 (5.90)	8.	V59 (9.80)	14.	V92 (7.83)
	3.	V43 (9.24)	9.	V61 (8.84)	15.	V94 (8.97)
	4.	V44 (10.00)	10.	V66 (9.23)	16.	V95 (9.70)
	5.	V46 (9.78)	11.	V75 (7.60)	17.	V98 (8.75)
	6.	V48 (8.90)	12.	V82 (7.91)		
3. Moderately susceptible (10-15 per cent damage)	18.	V2 (14.00)	28.	V47 (13.72)	37.	V76 (13.70)
	19.	V4 (14.60)	29.	V53 (13.50)	38.	V77 (14.21)
	20	V13 (11.75)	30.	V54 (14.04)	39.	V89 (11.00)
	21.	V31 (12.76)	31.	V55 (14.00)	40.	V90 (12.60)
	22	V34 (11.73)	32.	V56 (14.60)	41.	V99 (14.00)
	23.	V35 (13.10)	33.	V62 (13.40)	42.	V22 (10.92)
	24.	V38 (12.97)	34.	V64 (12.00)	43.	V32 (12.66)
	25.	V40 (13.20)	35.	V70 (11.50)	44.	V51 (14.05)
	26.	V41 (13.60)	36.	V72 (14.34)	45.	V60 (14.86)
	27.	V91 (12.90)				
4. Highly susceptible (more than 15 per cent damage)	46.	V1 (19.93)	67.	V15 (19.90)	88.	V28 (17.63)
	47.	V3 (30.21)	68.	V16 (18.70)	89.	V29 (19.45)
	48.	V5 (18.60)	69.	V17 (19.25)	90.	V33 (28.30)
	49.	V6 (15.90)	70.	V18 (17.82)	91.	V36 (20.10)
	50.	V7 (20.10)	71.	V19 (18.60)	92.	V37 (19.00)
	51.	V8 (26.60)	72.	V20 (18.50)	93.	V39 (23.80)
	52.	V9 (24.00)	73.	V21 (23.30)	94.	V42 (15.85)
	53.	V10 (17.80)	74.	V23 (26.60)	95.	V45 (22.95)
	54.	V11 (15.90)	75.	V25 (20.00)	96.	V49 (17.50)
	55	V12 (22.67)	76.	V26 (18.90)	97.	V50 (17.23)
	56.	V14 (22.00)	77.	V27 (21.30)	98.	V52 (22.60)
	57.	V57 (15.60)	78.	V84 (19.76)	99.	V79 (19.80)
	58.	V68 (24.17)	79.	V85 (22.34)	100.	V83 (23.00)
	59.	V65 (22.00)	80.	V86 (20.40)		
	60.	V67 (30.00)	81.	V88 (31.40)		
	61.	V69 (16.90)	82.	V93 (22.43)		
	62.	V71 (25.00)	83.	V96 (25.60)		
	63.	V73 (27.60)	84.	V97 (20.90)		
	64.	V78 (18 60)	85.	V100(45.00)		
	65.	V80 (21.76)	86.	V63 (28.50)		
	66.	V81 (29.70)	87.	V74 (20.50)		

Figures in brackets denote the mean per cent of flower damage

(Table 3) hundred varieties screened for pod damage. Fifty six varieties suffered maximum with a mean percent of damage ranging from 15.04 to 47.14. However a group comprising of twenty seven accessions showed moderate susceptibility with a percent of pod infestation which ranged from 10.5 to 14.04. Another set of seventeen accessions exhibited moderate resistance with a percent pod damage between 6.19 and 9.80. None of the accessions screened under field conditions indicated pod damages less than five per cent. Here too, there were no varieties to be included under the resistant category.

4.1.A. Laboratory study

4.1.A I. Selection of accessions on the basis of pod borer infestation in the field

On the basis of consistency in susceptibility rating in respect of flower and pod damage, fifteen accessions of cowpea were selected at the rate of five per group. Related details are presented in Table 4.

4.1.A.I a. Assessment of flower and pod damage by M. testulalis (Geyer) on caged cowpea accessions

The mean percent of flower and pod damage by M. testulalis (Geyer) when first instar larvae were released on caged cowpea plants are presented in Table 5 and 6 respectively.

Table 3. Classification of the cowpea accessions screened for pod infestation by *M. testulalis* (Geyer)

Rating	Accessions					
1. Resistant (5 per cent damage)	Sl. No.	Nil	Sl. No.	Nil	Sl. No.	Nil
2. Moderately resistant (5-10 per cent damage)	1.	V24 (7.10)	7.	V58 (9.45)	13.	V87 (9.60)
	2.	V30 (6.76)	8.	V59 (9.80)	14.	V92 (9.25)
	3.	V43 (7.80)	9.	V61 (9.20)	15.	V94 (8.30)
	4.	V44 (8.00)	10.	V66 (9 12)	16.	V95 (8.50)
	5.	V46 (7.00)	11.	V75 (6.72)	17.	V98 (6.60)
	6.	V48 (6.19)	12	V82 (7.50)		
3. Moderately susceptible (10-15 per cent damage)	18.	V2 (14.02)	27.	V47 (11.80)	36.	V72 (12.20)
	19.	V4 (15.00)	28.	V53 (12.38)	37.	V74 (10.70)
	20.	V13 (12.50)	29.	V54 (14.04)	38.	V76 (11.05)
	21.	V32 (12.50)	30.	V55 (13.40)	39.	V77 (11.30)
	22.	V34 (12.80)	31.	V56 (11.11)	40.	V79 (13.60)
	23.	V35 (12.80)	32.	V62 (12.93)	41.	V83 (10.50)
	24.	V38 (13.40)	33.	V63 (11.52)	42.	V89 (11.50)
	25.	V40 (12.80)	34.	V64 (11.20)	43.	V90 (13.40)
	26.	V41 (11.50)	35.	V70 (12.50)	44.	V99 (11.79)
4. Highly (15 per cent infestation)	45.	V1 (19.93)				
	46.	V3 (18.20)	64.	V23 (21.96)	82.	V60 (21.70)
	47.	V5 (20.40)	65.	V25 (19.40)	83.	V65 (29.14)
	48	V6 (15.42)	66.	V26 (19.10)	84.	V67 (16.85)
	49.	V7 (22.30)	67.	V27 (18.09)	85.	V68 (19.90)
	50.	V8 (17.48)	68.	V28 (15.67)	86.	V69 (20.80)
	51.	V9 (23.17)	69.	V29 (16.50)	87.	V71 (23.50)
	52.	V10 (15.90)	70.	V32 (20.00)	88.	V73 (24.50)
	53.	V11 (16.20)	71.	V33 (27.60)	89.	V78 (15.04)
	54.	V12 (30.00)	72.	V36 (18.80)	90.	V80 (19.62)
	55.	V14 (19.20)	73.	V37 (17.60)	91.	V80 (19.62)
	56.	V15 (17.10)	74.	V39 (19.40)	92.	V84 (17.80)
	57.	V16 (16.90)	75.	V42 (17.08)	93.	V85 (19.28)
	58.	V17 (15.92)	76.	V45 (23.10)	94.	V86 (16.50)
	59.	V18 (15.90)	77.	V49 (18.53)	95.	V88 (24.90)
	60.	V19 (16.00)	78.	V50 (16.12)	96.	V91 (16.85)
	61.	V20 (18.70)	79.	V51 (18.40)	98.	V96 (15.50)
	62.	V21 (19.10)	80.	V52 (19.66)	99.	V97 (16.96)
	63.	V22 (21.90)	81.	V57 (20.60)	100.	V100 (47.14)

Figures in brackets indicate the mean per cent pod damage

Table 4. Details of accessions selected for laboratory studies

Category	Susceptibility rating	Accessions
1	Resistant	Nil
2	Moderately résistant	V98, V30, V95, V61, V75
3	Moderately susceptible	V13, V41, V90, V89, V2
4	Highly suscepitible	V12, V1, V57, V86, V100

Table 5. Flower damage by *M. testulalis* (Geyer) on caged cowpea plants and the length of flower stalks

Accessions		Flower damage (per cent)	Treatment means	Mean flower stalk length (cm)
Resistant: Nil				
Moderately resistant				
	V98	10.00	0.316 ab (0.100)	7.50 a
	V30	7.76	0.278 a (0.077)	10.26 b
	V95	10.30	0.320 ab (0.101)	12.98 c
	V61	9.26	0.304 ab (0.093)	13.30 cd
	V75	9.89	0.314 ab (0.099)	12.98 c
Moderately susceptible				
	V13	12.26	0.349 abc (0.122)	13.25 cd
	V14	14.70	0.370 abc (0.147)	14.00 cd
	V90	13.16	0.355 abc (0.126)	14.10 cd
	V89	12.23	0.347 abc (0.120)	13.91 cd
	V2	15.00	0.387 abcd (0.150)	13.60 cd
Highly susceptible				
	V12	28.66	0.532 cd (0.283)	14.20 cd
	V1	27.00	0.519 cd (0.265)	14.00 cd
	V57	18.90	0.434 abcd (0.188)	14.60 cd
	V86	23.20	0.477 bcd (0.227)	14.75 d
	V100	33 00	0.574 d (0.330)	14.00 cd

Analysis was carried out after square root transformation.
Figures in parentheses are retransformed values.
Figures followed by common letters do not differ significantly at 5% level (DMRT).

As the data (Table 5) indicates, none of the varieties were resistant to the attack by the pest. Different varieties showed significant differences in the extent of flower damage by the pod flower larvae. There was a wide range in the percentage of flower damage, it being between 7.76 and 33.

The accession V30 suffered the least flower damage (7.76 per cent) followed by V61 (9.26 per cent) and V75 (9.89 per cent). The extent of flower infestation was ten per cent for the accession V98. There was a slight increase in the per cent of flower damage for V95, it being 10.30. But the analysis of variance revealed all these five accessions to be on par.

The accessions under the moderately susceptible category indicated 12.26, 14 70, 13.16, 12.25 and 15 per cent flower damage for the varieties 13, 41, 90, 89 and 2 respectively. All these five varieties were also on par with the varieties categorised under the moderately resistant group except for the variety V30. Therefore, V30 could be ranked as the most moderately resistant type. The percentages of flower damage for the members under the highly susceptible class were 28.66, 27.00, 18.90, 13.20 and 33.00 respectively for V12, V1, V57, V86 and V100. Accessions V57 and V86 were similar to V2 as per the statistical analysis. V12 and V86 indicated a higher flower damage and similar was the case with V1. The variety V100 could be ranked as the most susceptible one which suffered

Table 6. Pod damage by M. testulalis (Geyer) on caged cowpea accessions

Accessions		Pod damage (per cent)	Treatment means
Resistant:	Nil		
Moderately resistant			
	V98	8.90	0.296 ab (0.088)
	V30	7.13	0.267 a (0.071)
	V95	*10.33	0.314 ab (0.099)
	V61	10.00	0.316 ab (0.100)
	V75	*11.60	0.341 ab (0.116)
Moderately susceptible			
	V13	11.50	0.326 ab (0.106)
	V41	15.10	0.388 ab (0.151)
	V90	14.00	0.370 ab (0.137)
	V89	13.60	0.368 ab (0.135)
	V2	15.00	0.385 ab (0.148)
Highly susceptible			
	V12	27 33	0.521 bc (0.272)
	V1	21.40	0.459 abc (0.211)
	V57	23.23	0.479 abc (0.229)
	V86	23.10	0.479 abc (0.229)
	V100	39 66	0.629 c (0.395)

Analysis was carried out after square root transformation.
Figures in parentheses are retransformed values.
Figures followed by common letters do not differ significantly at 5% level (DMRT).

* Pod damage >10/

33 per cent flower damage. This was significantly different from all other varieties.

The differential response of the larvae of *M. testulalis* (Geyer) to the pods indicated in Table 6, reveals none of the accessions to be resistant to the pest. Those categorised under the moderately resistant class, had a lower per cent of pod damage. It was 8.90 for V98, 9.83 for V30, 10.33 for V95, 10.00 for V61 and 11.60 for V75. Though a range between 5 and 10 was taken as moderately resistant, V95 and V75 indicated a slight increase, it being 10.33 and 11.60 respectively. But all these five varieties were statistically on par. But V30 ranked the least with regard to the treatment means. Members of the next group, that is the moderately susceptible, had a higher per cent of pod damage. All the five varieties were statistically on par with regard to the treatment means. A higher percentage of pod damage was observed for all the five varieties categorised under the highly susceptible class. Here again, accession V100 had the maximum per cent infestation, it being 39 66 indicating its high susceptibility to the pest.

4.1.B. Influence of different accessions on the biology of *M. testulalis* (Geyer)

4.1.B.I. Evaluation of the larval survival on the flowers and pods

Laboratory studies to evaluate the larval survival of *M. testulalis* (Geyer) on the different accessions indicated a low percentage of survival for all the 5 accessions categorised under moderately resistant group (Table 7). It was just 20 per cent for V98 and V30. V95 and V75 had 26.6 per cent larval survival and it was 40 per cent for V61. Statistical analysis of the data revealed V98 as the most unsuitable, for it had a low treatment mean, it being 2.063 per cent. The percent survival was higher for the accessions categorised under the moderately susceptible class. It was 60, 66.60, 73.30, 73.30, 80 percentages respectively for V13, V41, V90, V89 and V2 While considering the treatment means, V13 and V41 were on par with V61 and V75. But all the five accessions in this class were identical. The highest per cent of survival was observed for the different accessions V12, V1, V57, V86 and V100 (Table 7). Though all these five ranked the same, V100 indicated the highest survival per cent, it being 100. With regard to their treatment means, this particular accession had the highest per cent which was 5.74. The former four accessions were statistically on par with those accessions grouped under the moderately susceptible class.

The per cent of *M. testulalis* (Geyer) larvae which pupated on the pods of different cowpea accessions are presented in Table 8. The variations were found to be significant between the varieties.

The per cent of larvae pupated on the pods of different cowpea accessions ranged from 18 to 90 per cent. The accessions

Table 7. Survival of the larvae of *M. testulalis* (Geyer) when reared on the flowers of cowpea accessions

Accessions		Survival on flowers (per cent)	Treatment means
Resistant: Nil			
Moderately resistant	V98	20.0	2.063 a (0.0013)
	V30	20.0	2.560 ab (0.0020)
	V95	26.6	2.917 abc (0.0026)
	V61	40.0	3.630 abcd (0.0040)
	V75	26.6	2.917 abcd (0.0026)
Moderately susceptible	V13	60.0	4.440 cde (0.0660)
	V41	66.6	4.670 cde (0.0066)
	V90	73.3	4.900 de (0.0073)
	V89	73.3	4.900 de (0.0073)
	V2	80.0	5.103 de (0.0079)
High susceptible	V12	86.6	5.333 de (0.0086)
	V1	80.0	5.130 de (0.0080)
	V57	93.3	5.537 de (0.0093)
	V86	86.6	5.333 de (0.0086)
	V100	100.0	5.740 e (0.0100)

Analysis was carried out after Sin^{-1} transformation.
Figures in parentheses are retransformed values.
Figures followed by common letters are not significantly different at 5 per cent level (DMRT).

Table 8. Survival of the larvae of M. testulalis (Geyer) when reared the pods of cowpea accessions

Accessions		Survival on pods (per cent)	Treatment means
Resistant :	Nil		
Moderately resistant			
	V98	20	2.526 a (0.0019)
	V30	18	2.376 a (0.0017)
	V95	20	2.560 a (0.0020)
	V61	26	2.908 a (0.0026)
	V75	22	2.642 a (0.0021)
Moderately susceptible			
	V13	60	4.434 b (0.0060)
	V41	68	4.722 ba (0.0068)
	V90	60	4.440 b (0.0060)
	V89	72	4.860 bc (0.0072)
	V2	70	4.788 bc (0.0070)
Highly susceptible			
	V12	86	5.316 c (0.0086)
	V1	80	5.122 bc (0 0080)
	V57	82	5.186 bc (0.0082)
	V86	80	5.110 bc (0.0079)
	V100	90	5.438 c (0.0090)

Analysis was carried out after $\sin^{-1}$ transformation.
Retransformed values are given in parenthesis.
Figures followed by common letters do not differ significantly at 5 per cent level (DMRT).

V98, V30, V95, V61 and V75 did not differ significantly with regard to the survival of M. testulalis (Geyer) larvae. The mean per cent of larval survival on these varieties were 20, 18, 20, 26 and 22 respectively.

Though there was a wide range of 60 to 72 per cent in the larval survival for the varieties V13, V41, V90, V89 and V2 giving 60% for V13 and V90, 68% for V41, 72% for V89 and 70% for V2, the statistical analysis indicated these five accessions grouped as moderately susceptible to be on par. But the accessions V41, V89 and V2 were also on par with accessions grouped as highly susceptible ones. Of the five accessions categorised as highly susceptible, V12 and V100 had the highest survival percentages and it was maximum for V100, it being 90 per cent.

4.1.B.II. Influence on the development duration

The influence of the different accessions on the duration of development of M testulalis (Geyer) larvae when reared on them, indicated the accession V100 to have the least duration (Table 9) The range in the development duration on the different accessions was between 13.33 and 18.0 days. The maximum development duration was for those reared on V98 and V30. There was a significant variation for the different accessions except V30 and V98. V95, V69 and V41 ranked next with a duration of 17.667 days. V75, V13, V90,

Table 9. Duration of development of *M. testulalis* (Geyer) when reared on cowpea accessions

Accession		Development duration (days)	Mean duration of development
Resistant.	Nil		
Moderately resistant			
	V98	18.00	18.000 d
	V30	18.00	18.000 d
	V95	17.60	17.667 cd
	V61	17.60	17.667 cd
	V75	17.30	17.333 bcd
Moderately susceptible			
	V13	17.00	17.000 bcd
	V41	17.30	17.667 cd
	V90	17.00	17.000 bcd
	V89	16.60	16.667 bcd
	V2	17.30	17.333 bcd
Highly susceptible	V12	16.00	16.000 bcd
	V1	15.30	15.333 ab
	V57	15.60	15.667 bc
	V86	15.30	15.333 ab
	V100	13.30	13.333 a

Figures followed by common letters do not differ significantly at 5% level (DMRT)

V89, V2 and V12 were all on par. Similar results were obtained for V1 and V86 which had a slightly higher duration (Table 9).

4.I.B.III. Influence on adult emergence

There was a significant variation in the mean per cent of adult emergence when the larvae of M. testulalis (Geyer) were reared on the pods of different cowpea accessions. The per cent of adult emergence was the least for V30 (Table 10), an accession grouped under the moderately resistant class. Two other accessions - V98 and V95 were also on par with V30 which had 20 and 26.6 percentage of adult emergence respectively. But the statistical analysis indicated the latter two varieties to be on par with V61 and V75 which had a slightly higher percentage of adult emergence. V61 had given similar results as that for V13, V41 and V89 grouped under moderately susceptible class. Within the accessions grouped in this category, there was an increase in the per cent of adult emergence from 40 to 50. But all the five were statistically on par. That variety which gave the maximum adult emergence percentage i.e. V90 (50 per cent) seemed to be on par with V12 which belonged to the highly susceptible group. V57 ranked next giving 70 per cent adult emergence followed by V1 and V86 giving an adult emergence percentage of 80. Maximum adult emergence was recorded for V100 which had 90 per cent adult emergence. So, of all the five, V100 seemed to be the most susceptible with regard to the percentage of adult

Table 10. Adult emergence of *M. testulalis* (Geyer) larvae reared on different cowpea accessions

Accessions		Adult emergence (per cent)	Treatment means
Resistant:	Nil		
Moderately resistant			
	V98	20.0	2.560 ab (0.0020)
	V30	10.0	1.810 a (0.0010)
	V95	26.6	2.947 abc (0.0026)
	V61	33 3	3.303 bcd (0.0033)
	V75	30.0	3.110 bc (0.0029)
Moderately susceptible			
	V13	40.0	3.630 bcde (0.0040)
	V41	43.3	3.747 bcde (0.0043)
	V90	50.0	4.040 cdef (0.0050)
	V89	40.0	3.607 bcde (0.0040)
	V2	46.6	3.910 cde (0.0046)
Highly susceptible			
	V12	60.0	4.430 defg (0.0060)
	V1	80.0	5.103 fg (0.0079)
	V57	70.0	4.763 cfg (0.0069)
	V86	80.0	5.123 fg (10.0080)
	V100	90.0	5.437 g (0.0090)

Analysis was carried out after $\sin^{-1}$ transformation.
Figures given in parentheses are retransformed values.
Figures followed by common letters do not differ significantly at 5 per cent level (DMRT).

emergence while considering the treatment means, it was the highest for V100. But this variety was on par with V12, V1, V57 and V86 which gave adult emergence percentages of 60, 80, 70 and 80 respectively (Fig 1)

4.1.B.IV. Influence of the accessions on sex ratio

The influence of cowpea accessions on the sex ratio of M. testulalis (Geyer) is presented in Table 11. It was interesting to note that the sex ratio was altered in the different accessions. There was a shift towards males for the accessions V98 and V30 in which 25 and 26.6 per cent were the proportion of females. V95 also ranked on par with the above two accessions which had 30 per cent female emergence. The other two accessions belonging to the moderately resistant group were significantly different from V98 and V30, but was on par with V95. Though a slight increase in the per cent of females was recorded for the five accessions belonging to the moderately susceptible category, they were not significantly different from V12 which belonged to the moderately susceptible category. V12 had 50 per cent female emergence Though an increasing trend was detected for the accessions V1, V57 and V86, a strong shift in favour of females was recorded with V100. It resulted in 60 per cent female emergence.

4.1.B.V. Influence of cowpea accessions on the reproductive rate of F_1 generation

The effect of exposure of the female moths of M. testulalis

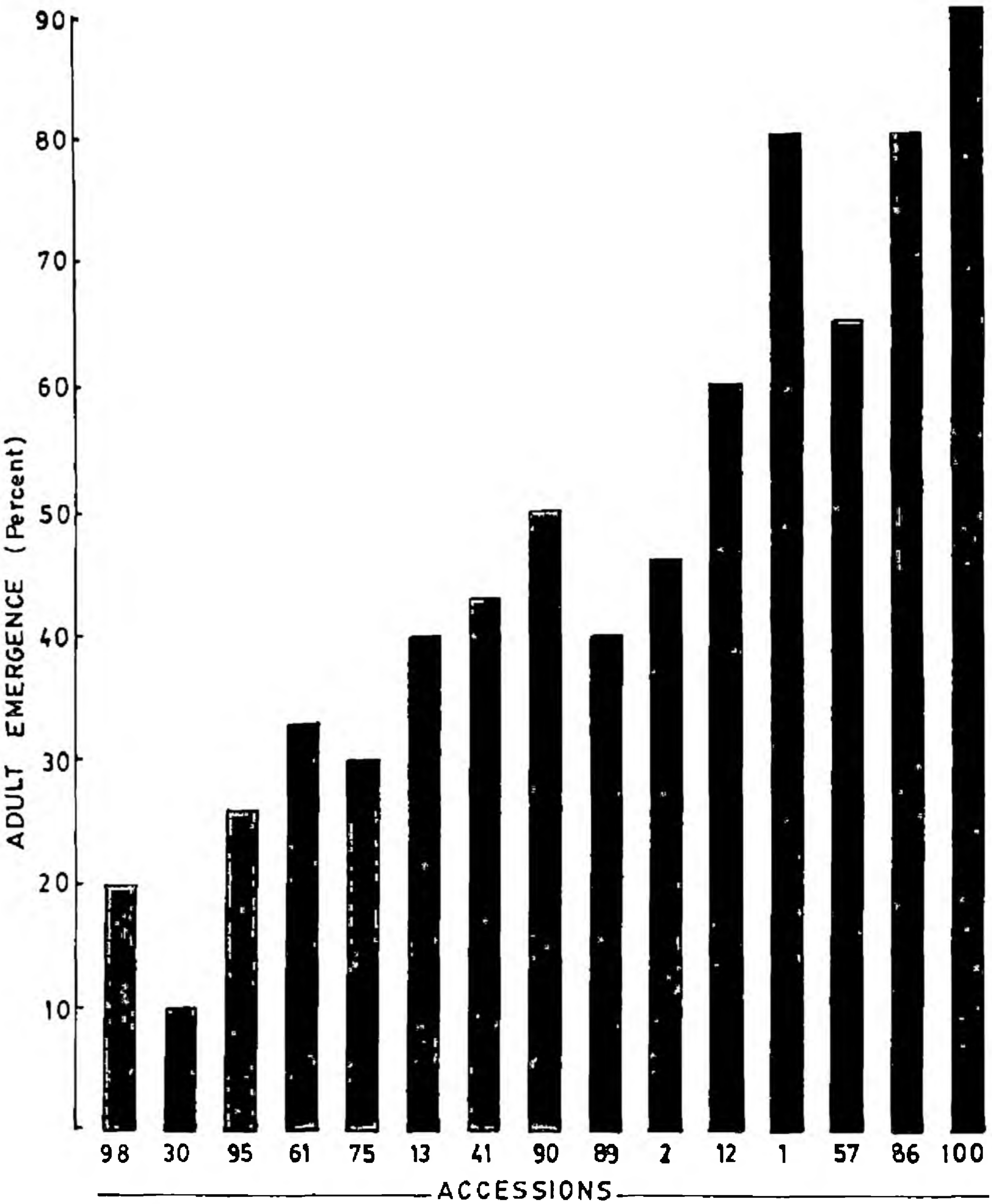

Figure I

The adult emergence trends of M. testulalis (Geyer) larvae reared on different cowpea accessions

Table 11. Sex ratio of *M. testulalis* (Geyer) when reared on different cowpea accessions

Accessions		Female moths (per cent)	Treatment means
Resistant:	Nil		
Moderately resistant	V98	25.0	0.250 a
	V30	26.6	0.267 a
	V95	30.0	0.300 ab
	V61	40.0	0.400 bc
	V75	41.6	0.417 bcd
Moderately susceptible			
	V13	45.0	0.450 cde
	V41	48.3	0.483 cdefg
	V90	46.6	0.467 cdef
	V89	48.3	0.483 cdefg
	V2	50.0	0.500 cdefg
Highly susceptible	V12	50.0	0.500 cdefg
	V1	53.3	0.533 defg
	V57	56.7	0.567 cfg
	V86	58.3	0.583 fg
	V100	60.0	0.600 g

Figures followed by common letters do not differ significantly at 5 per cent level (DMRT)

(Geyer) to different cowpea accessions on the reproductive rates is presented in Table 12. There was significant variation in their reproductive rate. The variety V98 had the minimum egg laying which was only 6.6 eggs/female moth. Maximum was recorded from those reared on V57, it being 25 eggs/adult female. Though the ones reared on V30 ranked next in their ability to deposit more counts of eggs, they were not significantly different from those reared on V75. The counts of eggs from those reared on V95 were were on par with V75, but varied significantly from V30. The next set among the moderately resistant group i.e. those reared on V61 was comparable with those reared on V95.

Considering the members of the moderately susceptible group, all the varieties (V41, V90, V89 and V2) except V13 were identical giving egg counts which ranged between 18.4 and 19. A slight increase in the reproductive potential was there with regard to V13 which gave 20.20 eggs/female. Though V86, an accession included under the highly susceptible category recorded on average of 21 eggs/female, it was not significantly different from V13 Adults from the variety V1 gave 22.20 eggs per female which were on par with V86. According to statistical analysis, they were on par with those from V12 and V100 which gave 24 and 25 eggs/female moth respectively.

Table 12. Mean number of eggs laid by the female moths of M testulalis (Geyer) when reared on the different cowpea accessions

Accessions		Number of egg per female moth	Mean number of eggs
Resistant:	Nil		
Moderately resistant			
	V98	6.60	2.567 a (6.60)
	V30	10.80	3.279 b (10.80)
	V95	16.00	3.992 cd (16.00)
	V61	17.80	4.217 de (7.80)
	V75	13.60	3.681 be (13.60)
Moderately susceptible			
	V13	20.20	4.492 cfg (20.20)
	V41	18.40	4.288 def (18.40)
	V90	19.20	4.380 def (19.20)
	V89	18.60	4.312 def (18.60)
	V2	19.00	4.358 def (19.00)
Highly susceptible			
	V12	24.00	4.894 hi (24.00)
	V1	22.20	4.708 fghi (22.20)
	V57	25.00	5.000 i (25.00)
	V86	21.00	4.578 efgh (21.00)
	V100	25.00	4.996 hi (25.00)

Analysis was carried out after square root transformation.
Means followed by common letters are not significantly different at 5 per cent level (DMRT).
Figures in parentheses are retransformed values.

4.2. Effect of different biophysical factors of the accessions on the pest distribution

4.2.A Pod wall thickness

There was a slight variation in the thickness of pod walls of different accessions. Though the four members of the moderately resistant group had the least thickness, V98 of the same group had an increased measure which was 66 mm. While considering the five different accessions under the moderately susceptible group, V90 had a lesser thickness which was on par with the former group under moderately resistant category. All the others were on par with V98. Similar was the case with the accessions of highly susceptible group where V12 had a lesser thickness and the others with an increased thickness. The pods walls of V1 had the maximum thickness, it being 84 mm.

A comparison of the mean pod wall thickness of the different cowpea accessions with the pod infestation by the pest indicated no significant correlation between them (Table 13).

4.2.B. Length of flower stalk

While considering the flower stalk length of the different accessions under study, it was evident that the variation was little. Of the 15 varieties, V98 had flower stalks with the least measurement, it being 7.5 cm. V30 which also belong to the moderately resistant group, ranked next which had a 10.26 cm long flower

Table 13. Correlation coefficient between the mean podwall thickness of the different accessions and per cent pod infestation by *M. testulalis* (Geyer)

Mean pod wall thickness (mm)	Mean per cent pod damage
Mean pod wall thickness	r = 0.2781 (Not significant)

Table 14. Correlation coefficient between the mean length of flower stalks of the accessions and per cent flower damage by *M. testulalis* (Geyer)

Mean length of flower stalks (cm)	Mean per cent of flower damage
Mean length of flower stalks	r = (+) 0.4972

Table 15. Configuration of calyx in the flowers of cowpea accessions

Group	Accessions
Tight	V98, V30
Semi-tight	V95, V61, V75
Partially free	V13, V41, V90, V89, V2
Free	V12, V1, V57, V86, V100

stalk. Two other accessions of the very same group (V95 and V75) showed a slight increase which was on par with V61. All the five accessions of moderately susceptible group and four from the highly susceptible group were on par with V61. The range in the length of flower stalk was between 13.30 and 14.60 cm. Maximum length was recorded for the flowers from V86 accession

The correlation coefficient between the mean length of flower stalks of the different accessions and the mean per cent of infestation of the inflorescence by the larvae of M. testulalis (Geyer) are presented in Table 14 The per cent flower damage was found to be correlated positively with the mean length of flower stalks (r = 0.4972).

An overall comparison of the flower stalk length and per cent flower damage revealed a lesser infestation with those flowers having shorter flower stalks. With an increase in the length of flower stalk, a simultaneous increase in the percentage of flower damage was also observed (Table 15).

4.2.C. Configuration of calyx

Categorisation of the different accessions on the basis of the configuration of calyx indicated only two accessions to have a tight pattern (Table 15) V95, V61 and V75 which had major portion of sepals tight with the tips being free could be grouped under semitight. V13, V41, V89, V90 and V2 had major portion of sepals free with their basal portion tight. So all these five could be classed under partially free. The rest five i.e. V12, V1, V57, V86 and V100 which had the sepals completely free were classed under the free group. Since there was no unit measurements for this categorisation, correlation studies could not be conducted. But a superficial comparison indicated the accessions which had flowers with tight or semitight calyx to be moderately resistant. Those with partially free calyx were moderately susceptible. All the five accessions under the highly susceptible group had flowers with free calyx.

4.2.C.I. Disposition of corolla

Classification of the accessions on the basis of the nature of corolla indicated V98, V95, V61, V13, V2, V30 and V75 to have the petals loosely arranged in the flowers. So all these seven accessions were grouped under 'loose category (Table 16). The rest of the accessions under study (V12, V1, V41, V89, V57, V100, V90 and V86) had the corolla compact in the flowers and hence grouped under compact class.

4.2.C.II. Nature of seed testa

Observations recorded on the thickness and colour of the seed testa are presented in Table 17. The seed testa were thick for V98, V30, V2 and V61. Thinner testa were observed for the

Table 16. Classification of the accessions based on the disposition of corolla

Group	Accessions
Loose	V98, V95, V61, V13, V2, V30, V75
Compact	V12, V41, V89, V1, V57, V100, V90, V86

Table 17. Classification of cowpea accessions based on the nature of the seed testa

Accessions	Thickness of testa	Colour of testa
V98	Thick	Purple
V30	Thick	Light green
V95	Thin	Cream
V61	Thick	Light green
V75	Thin	Light green
V13	Thin	Light green
V41	Thin	Cream
V90	Thin	Black
V89	Thin	Light green
V2	Thick	Black
V12	Thin	Light green
V1	Thin	Cream
V57	Thin	Cream
V86	Thin	Black
V100	Thin	Cream

rest eleven accessions. All five accessions of the susceptibles group seemed to possess thin seed testa.

Five of the accessions (V30, V61, V75, V13 and V12) had seed testa light green in colour. Cream was the colour for the seeds from accessions V100, V41, V1, V57 and V95. Accessions V90, V86 and V2 gave seeds which had black testa and it was purple for V98. No correlation was observed between the colour of the seed testa and pest infestation.

4.2 C III. Disposition of the seeds in the pods

The classification of the different accessions on the basis of the arrangement of seeds in pods is presented in Table 18. The different accessions which had seeds very loosely arranged in the pods were V98, V30, V95, V61 and V75. In the accessions V41, V90, V2 and V12, the seeds were moderately close. A close packing of the seeds were observed in the accessions V100, V89, V13, V86, V57 and V1. No correlation was worked out between the seed distribution and the rate of pest infestation. Moderately resistant varieties seem to have a loose packing of seeds. All the highly susceptible varieties except V12 had close packing of the seeds within their pods. The rest four varieties had the seeds packed moderately closer.

Table 18. Classification of accessions based on the disposition of seeds in the pods

Group	Accessions
Close	V100, V89, V13, V86, V57, V1
Moderately close	V41, V90, V2, V12
Loose	V98, V30, V95, V61, V75

Table 19. Classification based on the pubescence of the pods of cowpea accessions

Class	Accessions
Glabrous	V98, V75, V2, V1, V100
Sparsely pubescent	V61, V41, V96, V12
Pubescent	V30, V13, V89, V57
Densely pubescent	V95, V12

4 2 D. Pubescence of the pods.

Classification of the accessions on the basis of counts of trichomes on the pod surface from a unit area indicated five of the accessions to have a glabrous nature (Table 19). They were V98, V75, V2, V1 and V100. Trichomes were sparsely spread on V61, V41, V96 and V12. Pubsecent nature was observed on the variety V30, V13, V89 and V57. It was densely pubescent for V95 and V12. It is quite evident from the observations that the pubescent/glabrous nature of pods was not a criterion for the spread of the pest.

4.3. Influence of the Biochemical components of the accessions on the pest incidence

4.3.A. Assay of the pods for total sugar

Results of the analysis carried out by to determine the percentage of total sugar content in the different cowpea accessions are summarised in Table 20. It revealed a range from 2.8 to 6 per cent in the concentration of total sugars. The minimum percentage of total sugars was detected in accession V30. It was slightly higher in V98 and V75. Statistical analysis did not reveal any significant variation between these three. V61 which also belonged to the above group, showed no significant variation from V75 where the mean per cent of total sugars was 3.2. The fifth member of this group i.e. V95 had a slightly higher concentration which was significantly different from V95 and V98. Among the moderately

Table 20. Detection of total sugars and amino acids in the pods of cowpea accessions

Accessions		Total sugars (mean per cent)	Total amino acids (µg/g)
Resistant:	Nil		
Moderately resistant			
	V98	2.900 ab	0.423 a
	V30	2.800 a	0.517 ab
	V95	3.367 c	0.623 abc
	V61	3.200 bc	0.677 bcd
	V75	3.000 abc	0.700 bcd
Moderately susceptible			
	V13	4.500 ef	0.850 cde
	V41	4.100 d	0.843 cde
	V90	4.183 de	0.833 cde
	V89	4.750 fg	0.877 de
	V2	4.817 fg	0.967 ef
Highly susceptible			
	V12	5.200 h	0.933 e
	V1	6.000 i	1.833 h
	V57	5.733 i	1.667 gh
	V86	5.000 gh	1.167 f
	V100	5.733 i	1.507 g

Figures followed by common letters do not differ significantly at 5 per cent level (DMRT) susceptible group, V41 had the least sugar content. It was higher for accessions V89 and V2 which were 4.75 and 4.817 respectively. These two accessions were on par. An increasing trend was observed for the different accessions of the highly susceptible group. The mean per cent of total sugars was 5.2 for V12 and still higher for V57, V100 and V1. Though it was 6 per cent for V1, V57 and V100 ranked on par with it.

The correlation coefficient of total sugars and the mean per cent of infestation in the pods of these accessions is worked out and presented in Table 21. It was seen that the per cent of pod damage in the accessions was positively correlated to the contents of total sugars in their pods.

It is evident from the results that, accessions with lower contents of total sugars were moderately resistant. With an increase in its content, the accessions were moderately susceptible. The highly susceptible group had the highest per cent of total sugars.

4.3.B. Assay of amino acids

Estimation of amino acids in the different accessions indicated the lowest amino acid content for the accession V30 (Table 20). Though an increase in the concentration of total amino acids was seen for V98 and V95, these two accessions were not statistically different from V30. V61 and V75 recorded 0.677 and 0.7 μg/g of

Table 21. Correlation coefficient of total sugar and mean per cent of pod damage by _M. testulalis_ (Geyer)

Mean content of total sugar (%)	Mean percentage of pod damage
Mean content of total sugar in the accession	r = (+) 0.7109

Table 22. Correlation coefficient between the mean content of total amino acids in the pods and the mean per cent of pod damage by _M. testulalis_ (Geyer)

Mean content of total amino acids (ug/g)	Mean percentage of pod damage
Mean content of total amino acids in the pods of the accessions	r = (+) 0.6640

amino acids which were not statistically different from each other, as per the statistical analysis of the data.

There was an increase in the amino acid content for the different accessions of the moderately susceptible group. V13, V41 and V90 were all on par. The accession V2 had a higher content of amino acid which was 0.967 µg/g. All the accessions under the highly susceptible group had a still higher content of amino acids. Though V57 and V100 had almost the same concentration of amino acid in them, V1 which had 1.833 µg/g ranked highest in the amino acid content.

When the correlation between the mean content of total amino acids in the pods and the per cent of pod damage by the borer was worked out, the resulting value of r = (+) 0.664 indicated a high correlation between them (Table 22). It is also evident from the data that all the members of the moderately resistant group had a lower amino acid content. It seemed to be increasing for the accessions under the moderately susceptible group. The amino acid concentration was the highest for the members under the highly susceptible group.

4.3.C Assay of total nitrogen and crude protein

The results of the analysis of the pods of different cowpea accessions for total nitrogen and crude protein are presented in Table 23.

Table 23. Total nitrogen and crude protein contents in the pods of cowpea accessions

Accessions	Total Nitrogen (%)	Crude protein (%)
Resistant:	Nil	
Moderately resistant		
V98	2.533 b	15.835 b
V30	2.070 a	12.937 a
V95	2.960 c	18.500 c
V61	3.133 cd	19.587 cd
V75	3.300 de	20.627 de
Moderately susceptible		
V13	3.567 cf	22.293 cf
V41	3.667 fg	22.920 fg
V90	2.967 c	18.543 c
V89	3.900 gh	24.377 gh
V2	3.900 gh	24.377 gh
Highly susceptible		
V12	3.833 fg	23.963 fgh
V1	4.217 i	26.357 i
V57	4.600 j	28.753 j
V86	4.117 hi	25.730 hi
V100	4.233 i	26.460 i

While taking into consideration the total nitrogen alone, it was lesser for the members under moderately resistant group. Minimum concentration was detected for V30 which was only 2.07 per cent. Of the five accessions under the moderately susceptible group, lowest per cent of total nitrogen was for V90, which was only 2.967. The variety V90 was on par with V95, a member from the moderately resistant group. There was no variation with regard to V89 and V2 which had 3.9 per cent of total nitrogen. An increasing trend was observed for the members under the highly susceptible group where the range was 3.833 to 4.6 per cent. Maximum amount of total nitrogen was detected in the pods of V57, a member from the highly susceptible group.

Correlation coefficient between the mean per cent of total nitrogen in the accession and the percentage of pod damage by the pest revealed a positive correlation (Table 24). It is also clear from the data that the highest nitrogen content was there for a member from the highly susceptible group. It was the least for V30 which belonged to the moderately resistant group. Medium was the percentage of total nitrogen for those accessions under the moderately susceptible group.

Detection of crude protein also gave very similar results. Here again, V30 had the least crude protein percentage, which was only 12.937 (Table 23). V98 ranked next where the percentage of crude protein was 15.835, closely followed by V95 which had 18.5 per cent of crude protein. Though the percentage of crude protein for V61 was 19.587, this was not significantly different from V75 which had 20.627 per cent crude protein.

Of all the five members under the moderately susceptible group, V90 had the least crude protein content which was on par with V95. An increase in the percentage of crude protein was observed for V13 and V41, but they were statistically on par. Similar was the case with V89 and V2 which had 24.377 per cent of crude protein. Though all the five members of the highly susceptible group had an increased crude protein indication, it was maximum for V57. V1 and V100 which had a slightly lesser content of crude protein showed no significant difference between them.

Correlation coefficient was worked out for the detection of the influence of crude protein in the pods on infestation by the pod borer (Table 25). Those accessions with lower levels of crude protein suffered lesser pod infestation rates It was increasing with increased concentration of crude protein. Maximum pod damage was identified for those accessions with higher crude protein levels.

Table 24 Correlation coefficient between the mean per cent of total N in the accessions and the percentage of pod damage by M. testulalis (Geyer)

Mean content of total nitrogen (%)	Mean per cent of pod damage
Mean per cent of total nitrogen in the accessions	r = (+) 0.6398

Table 25. Correlation coefficient between the mean per cent of crude protein in the pods of the accessions and the percentage of pod damage by M. testulalis (Geyer)

Mean content of crude protein (%)	Mean per cent of pod damage
Mean per cent of crude protein in the accessions	r = (+) 0.63

Discussion

5. DISCUSSION

Recent years have witnessed progressive changes in the insect pest complex of vegetable crops. Consequent on the introduction of HYV/cultivars/types, several species of minor pests have attained the status of major pests due to change in agroecosystem. In Kerala, considerable loss are caused to cowpea on account of infestation by the pod borers particularly M. testulalis (Geyer). As direct insecticidal control of the pest is very difficult, several rounds of prophylactic application of insecticides will be needed. Since this approach is not advisable due to hazards from terminal residues, it was intended to screen the germplasm reserves consisting of cultivars/types/varieties of cowpea with reference to their susceptibility of M. testulalis (Geyer) under natural conditions and thus to categorise them into different clustures on the basis of their innate resistance traits with a view to identify promising sources of resistance. The study of the biophysical and biochemical basis of resistance to M. testulalis (Geyer) was also envisaged to understand the mechanism of resistance. The results generated in these studies are discussed in this chapter.

5.1. Field screening of cowpea lines for resistance to M. testulalis (Geyer)

5.1.a. Flower damage

The response of M. testulalis (Geyer) on 100 cowpea varieties were evaluated by raising double rows of cowpea plants with ten plants in each row. The results of the experiment which was replicated twice indicated drastic differences (Table 2). The range of infestation revealed that the tested accessions possessed high variability in respect of their relative susceptibility to the pod borer infestation.

Of the 100 accessions screened, the flowers of 55 varieties seemed to have heavy infestation by the larvae and hence they were categorised under the highly susceptible group. Twenty eight accessions were grouped as moderately susceptible and seventeen of the accessions were grouped as moderately resistant. Since there were no accessions with a per cent flower damage less than 5, none of the accessions were categorised under resistant group.

5.1.b. Pod damage

Identical to the above results were the observations with regard to the extent of damage by the borer on the pods. Of the 100 varieties screened, 56 varieties suffered the maximum damage and they were included under the highly susceptible category.

Among the rest of the accessions, 27 had moderate susceptibility and 17 exhibited moderate resistance. Here too, there were no varieties to be included under the resistant category (Table 3).

Of the different comprehensive reviews of the various aspects of insect resistance in cowpea which have been made by several workers, there were a few reports indicating resistance by the crop to *M. testulalis* (Geyer). Singh (1978) identified the two cowpea varieties TVU 946 and TVU 4557 as resistant to the legume pod borer based on his experiments at IITA. Singh and Jackai (1983) and Jackai (1981) have shown the existence of cowpea resistance to the legume pod borer. Jackai (1982), while developing a method for screening resistance of cowpea to the legume pod borer *M. testulalis* (Geyer), had identified TVU 946 to be the most resistant cultivar in every category of assessment. The same variety resulted to be the most resistant both in the flowering and pre-flowering stage followed by Ife Brown and Vita-1 as reported by MacFoy *et al.* (1983) from their greenhouse investigations.

Nilakhe and Chalfant (1982) had screened 20 cowpea cultivars for resistance to 9 different insect pests in the field planting. Cultivars differed significantly in the degree of susceptibility to different pests and he had concluded that the chance of a cultivar to be resistant to several of the insect pests were rare. The present study rules out the chance of any of the 100 varieties screened, to be resistant to this particular pest.

5.1.A **Laboratory study**

Flower and pod damage

For the evaluation of the mean per cent of flower and pod damage by *M. testulalis* (Geyer), laboratory reared larvae were released on the isolated plants. From the data on the total number of flowers in relation to the number of flowers infested as well as the total number of pods in relation to number of pods infested, the infestation percentages were worked out. Results have revealed a wide range in the flower and pod damage. The accession V30 suffered the least flower as well as pod damage. Therefore, V30 was ranked as the most moderately resistant accession. The variety V100 was observed to be the most susceptible one which suffered 33% flower damage and 39.66% pod damage (Table 5). None of the varieties was resistant to the pest. These results confirmed the findings from the field trial. Hence, among the 100 accessions taken for trial, V30 could be considered as the most moderately resistant type and V100 the most susceptible one. No earlier reports of laboratory investigations were available to substantiate these findings.

5.1.B. Influence of different accessions on the biology of *M. testulalis* (Geyer)

5 1.B.I. Larval survival on the flowers and pods

A low per cent of survival for all the five accessions categorised under the moderately resistant group was the result of an evaluation of the larval survival on flowers. As the accession V98 had a treatment mean of 2 063 (Table 7) which was the least among this group, this particular accession was found to be the most unsuitable host for the larvae. While considering the moderately susceptible group, the survival seemed to be higher for the different accessions. The accession V100 indicated the highest survival per cent, it being 100.

A record of the percentage of M. testulalis (Geyer) larvae pupating on the pods revealed a wide range of 18 to 90 per cent on the different cowpea accessions. Minimum larval survival was recorded on V30 and the maximum which was 90% for V100 (Fig.2) This wide variation in the survival of this pest could be due to antibiosis which the host plant might have exercised on insect development as reported by Painter, 1966; Jayaraj, 1967a; Chari et al., 1976; Karel et al., 1980 and Gurumukhi et al., 1983.

A low per cent of larval survival on the moderately resistant varieties is in conformity with the results reported by Ofuya et al., 1986. They had reported the cowpea varieties TVU 3709 and BPL-31 as resistant to the black cowpea moth C. ptychora (Meyrick) where the larval mortality rates were found to be very high. Chelliah and Sambandam (1974) evaluated the mechanism of resistance in C. callosus for the fruit fly D. cucurbitae Coq. A very low larval survival was exhibited by the fruit flies reared on resistant hosts. This result is very much in concurrence with the present finding. Messina et al. (1985) observed high mortality rates of the cowpea aphids when they were reared on the resistant cowpea varieties. Antibiosis was manifested as decreased survival in cowpea genotype TVX-3236 resistant to the bean flower thrips, M. sjostedti (Trybom) (Salifu et al., 1988). A similar report was from Hammond and

Cooper (1989) which stated that, in the soybean (Glycine max (L.) Merr.) germplasm lines resistant to the Mexican bean beetle E. varivestis Mulsant, the mortality rates of larvae were higher compared to that in the susceptible lines.

From the above findings, it could be interpretted that among the different accessions categorised under the moderately resistant group, V30 possesses antibiosis mainly in the form of larval mortality of M. testulalis (Geyer). None of the accessions under the moderately susceptible group varied significantly in respect of this trait. Among the accessions under the highly susceptible group, V100 provided ideal condition for the maximum larval survival.

5.1.B.II. Development duration

The investigations to record the influence of different cowpea accessions on the development of the pest revealed wide variations. Among the five accessions under the highly susceptible group, the accession V100 seemed to have a positive effect on the pest. A minimum duration was needed for those larvae exposed to this particular variety (Table 9). Though the members of this group had a comparatively lesser developmental span, it was comparable with those accessions under the moderately susceptible group. But, taking the moderately resistant varieties into consideration, V30 and V98 resulted in a prolonged development duration.

The results reported by Jayaraj (1967) shows that the nymphal period of the leaf hopper, E. flavescens (F.) was prolonged when fed on the resistant Baker and Cooner varieties. A similar report from Ofuya et al. (1986) stated that Vita-5, a resistant cowpea variety prolonged the larval duration of the black cowpea moth, C. ptychora (Meyrick). In this, the larvae were slower in developing into adults than on other varieties. Antibiosis was manifested as extended immature developmental period in cowpea genotype TVX 3236 resistant to the bean flower thrips, M. sjostedti (Trybom.), according to Salifu et al. (1988).

In the present studies, it was found that among the different accessions grouped under the highly susceptible class, the accession V100 showed a positive effect on the pest. The larvae had completed their juvenile stage within 13.33 days. Quite contrary was the result with those reared on varieties V30 and V98. Here, there was a prolongation in the larval duration which was 18 days. This wide variation exhibited by the two groups could be due to antibiosis within these cowpea varieties.

5.1 B.III Adult emergence

The larvae of M. testulalis (Geyer) when reared on the pods of different cowpea accessions revealed significant variations in the adult emergence percentage. It was the least for those larvae reared on variety V30, an accession grouped under the moderately resistant class (Table 10). Here the adult emergence was only 10%. Within the accessions grouped under the moderately susceptible class, an increase in the per cent of adult emergence was evident. Maximum per cent of adult emergence (90%) was recorded for the variety V100 which was classified under the highly susceptible group. This wide variation could be due to antibiosis inherent in the resistant cowpea accessions.

Jayaraj (1967) in his detailed studies on the influence of antibiosis in castor varieties to the leaf hopper E. flavescens (F.) revealed that the percentage of nymphs becoming adults were lower in the resistant varieties. The present finding agrees with the above report. It shows that the susceptible accessions favoured high adult emergence trends whereas the resistant ones proved to be detrimental to the pest.

5 1.B.IV. Sex ratio

Laboratory trials carried out under confinement to identify the influence of cowpea accessions on the sex ratio of M. testulalis (Geyer) resulted in interesting conclusions (Fig. 4). It was found that the sex ratio was altered in the different accessions. A shift in the sex ratio in favour of males was observed for the accessions V98 and V30 which belonged to the moderately resistant group. A similar shift in favour of males with only a slight increase in the per cent of females was recorded for the 5 accessions belonging to the moderately susceptible group (Table 11). For the accessions V1, V57 and V86, an increasing trend with regard to the percentage of females was detected. A stronger shift in favour of females was recorded with V100, a member of highly susceptible group. Here the percentage of female emergence was 60, which was the maximum.

The antibiotic effect of the resistant wild melon, C. callosus on the fruit fly D. cucurbitae Coq. was investigated by Chelliah and Sambandam (1974). The fruit fly larvae reared on the resistant host which registered a low larval survival and low growth index had a direct effect on the sex ratio. Those flies reared on resistant melon had resulted in a less number of female adult emergence, than from the susceptible fruits. These results agree with the report of Panda and Das (1975) where a higher female/male ratio of L. orbonalis Guen. was obtained is susceptible brinjal accessions. An altered sex ratio was the result when the pod borer, A. atkinsoni Moore was reared on resistant lab lab cultivars (Chakravarthy, 1978). Similar observations were recorded by Lall and Sukhani (1982) in the case of C. partellus (S.) reared on sorghum varieties.

The results of the present investigation which has a lowered female proportion in the resistant strains and a higher proportion of females in the susceptible ones could also be due to the antibiotic effect of the host plant on M. testulalis (Geyer). This increase in the proportion of females for those insects reared on susceptible strains of cowpea could be due to positive stimulation of neuro hormonal activity induced by those accessions. This is normally expected because in susceptible accessions, the faster increase in pest populations could be ensured only if there is a dominance of females. This may perhaps be due to the selective larval mortality of would be females in the resistant types due to nutritional constraints.

5.1.B.V. Fecundity

Day to day observations recorded for the presence of eggs on flowers and flower buds assisted in working out the mean number of eggs laid by a single female moth. The data presented in Table 12 clearly reveals the effect of different cowpea accessions on the reproductive rate. The number of eggs laid by the female moths when reared on the different cowpea accessions was found to be significantly different. The variety V98 closely followed by V30 received the minimum number of eggs per female moth. Taking into consideration the members of the moderately susceptible group, all the varieties exhibited a slight increase in the reproductive potential. Of the 5 accessions grouped under the highly susceptible class, maximum was the count of eggs

The results of the studies on the reproductive potential of M. testulalis (Geyer) showed an improvement in fecundity in the case of accessions belonging to the highly susceptible class as compared to the moderately resistant ones. An increase in the fecundity of the leaf hopper, E. flavescens (F.) when reared on susceptible castor varieties was reported by Jayaraj, 1967. In a similar report, lower population of aphids was observed on the resistant cowpea varieties compared to the susceptible ones (Panda and Raju, 1972; Chari et al., 1976). In another report, Chelliah et al. (1974) suggested that the fecundity of the fruit fly D. cucurbitae Coq. reared on the resistant hosts registered lower values. Chakravarthy (1978) reported great difference in the preference for oviposition, by the adult moths of A. atkinsoni Moore among cowpea cultivars. Some susceptible cultivars including a local variety and EC-28826, recorded more number of eggs as compared to the resistant accessions. The resistant varieties namely, PLS-24 and PLS-16-1 had no eggs or a fewer number of eggs on them.

Intensive green house screening of cowpea for varieties for resistance to C. ptychora (Meyrick) by Ezueh (1981) demonstrated that the fecundity of female moths was greatly reduced in the resistant wild cowpea V. unguiculata sub sp. mensensis and two closely related cultivars of V. unguiculata (L.) Walp, TVU 946 and TVU 2994. Low -fecundity of the cowpea aphids was observed on the resistant cowpea plants by Messina et al., 1985. Another report by Ofuya et al. (1986) stated the cowpea varieties TVU 3709 and BPL-3-1 to be resistant to the black cowpea moth, C. ptychora (Meyrick). Females reared on them had the lowest fecundity. Jayappa and

Lingappa (1988) found out that the mean progeny per aphid reared on the resistant variety namely P-912 was significantly lower than these reared on the susceptible and highly susceptible varieties. The resistant variety restricted the rate of reproduction to a minimum whereas the susceptible and highly susceptible entries recorded the maximum progeny.

The present study showed that the stimulation of reproductive potential of the test insect is dependent on the accession on which they were reared. Antibiosis might have been responsible for the increase in reproductive potential. The lowered counts of eggs on the moderately resistant accessions might be due to non-preference by the test insect for oviposition. While investigating the mechanism of resistance in cowpea to the Southern green stink bug, N. viridula (L.), Schalk et al. (1986) revealed that tolerance was the mechanism of resistance exhibited by the promising lines.

5.2. Biophysical components

5.2.A. Pod wall thickness

As the incorporation of pod wall resistance into commercial varieties of cowpea would lessen the two most objectionable results of borer pest infestation - seed injury and larval contamination, pod wall thickness of the various varieties under consideration was measured Results of this investigation indicated a slight variation in the thickness of the pod wall of different accessions (Fig. 5).

There was no significant correlation between the pod wall thickness and the per cent of pod damage. The mean pod wall thickness was the lowest for the moderately resistant accession V95. All the members of the moderately susceptible group except V90, recorded thicker pods. Similar was the results with the accessions belonging to the highly susceptible class.

It was reported by several workers that in brinjal, the hardness of the fruit skin and flesh due to compact seed arrangement hindered the entry of fruit and shoot borer, L. orbonalis Guen. in resistant varieties of brinjal (Srinivasan and Basheer, 1961; Krishnaih and Vijay, 1975 and Lal et al., 1976). Investigations on cowpea indicated a negative correlation between successful pod wall penetration by the curculio, C. aeneus (Boh.) and pod wall thickness. But no association was noticed between pod wall thickness and resistance to the curculio, according to Ennis and Chambliss (1976). Similar observations were recorded in L. lab niger (L.) cultivars, where the pod wall thickness didn't form a physical barrier to the entry of the larvae of the pod borer, A. atkinsoni Moore (Chakravarthy, 1978). A similar report by Ezueh, 1981 stated that there was no correlation between pod wall thickness and resistance to the cowpea moth, C. ptychora (Meyrick). Identical results were given by Chiang and Singh (1988) who investigated the correlation between pod wall thickness and the level of incidence of the pod sucking bug, C. tomentosicollis (Stal.). They reported that no increased pod wall thickness was observed in the highly resistant cowpea cultivar V. vexillata as compared to V. unguiculata (L.) Walp. All the above results corroborate the present finding, where there was no correlation between the pod wall thickness and the level of pod borer infestation.

5.2.B. Length of flower stalk

When the effect of length of peduncle on the pest distribution was evaluated for the different accessions, the accessions didn't seem to show significant variation (Fig. 6). The accession V98 which belonged to the moderately resistant group had the shorter flower stalk But while the correlation coefficient between the mean length of flower stalk of the different accessions and the mean per cent of infestation of the inflorescence by the larvae was calculated, the per cent flower damage was found to be correlated positively with the mean length of flower stalk. A general comparison of the flower stalk length and per cent flower damage indicated lesser infestation with those flowers having shorter flower stalks. The results were just the reverse for those accessions which had lengthier flower stalks. A simultaneous increase in the flower damage was noticed on long peduncles.

Results of the present investigation closely resemble the reports by Khaemba (1985) in which the peduncle length was identified to be a factor determining intensity of pod damage in cowpea.

The cultivars with short peduncles were more resistant to the pod sucking bug, R. dentipes (Fabricius) and A. curvipes (Fabricius) than those with long peduncles. Quite contrary to the above results, a reduction in the per cent infestation was attributed to long peduncles which helped to hold the pods upright over the plant canopy leading to lesser damage by the borers (IITA, 1974, 1975; Singh, 1978).

5.2.C. Configuration of calyx

The pot culture studies with fifteen selected accessions revealed a uniformity in the configuration of calyx for the accessions within each group. Accessions under the moderately resistant group possessed tight or semi tight calyx. Those accessions under the moderately susceptible group were with partially free calyx and the calyx was free for five of the accessions under the highly susceptible group (Table 15). It was thus found, that the accessions had some inherent defence mechanism at varying levels when the different groups were compared. The report by Roesingh (1980) on the same crop concludes antibiosis to be the cause for a lower level of thrips M. sjostedti (Trybom) larvae. He had related this to the inability of the larvae to pierce their way which made it unable to feed effectively in the compact tissue. The parenchyma cells of the calyx were seen to be closely packed. Reports from Panda et al. (1971), Chelliah and Srinivasan, 1983, attribute the tightness of calyx to be the cause for hindering initial entry of the larvae of L. orbonalis Guen. into brinjal fruits.

5.2.C.I. Disposition of corolla

Pot culture experiment for the evaluation of the influence of corolla pattern on the pest distribution had resulted in 7 of the 15 accessions to have petals loosely arranged in the flowers. The rest 8 accessions seemed to have a compact corolla (Table 16). As these data were purely on the visual observations, no statistical analysis was possible But a prominent character observed was that, of the 7 accessions belonging to the former category, 5 belonged to the moderately resistant class. The accessions grouped under the second category were either moderately or highly susceptible to the pest. The lower spread of the pest on those flowers with free corolla or a higher existence of the pest on accessions with compact corolla could be due to antibiosis. The open out nature of the corolla might be unfavourable for the pest. Similarly, the compact nature of the flowers was influencing the pest by giving an ideal condition for their survival.

5.2.C II. Nature of seed testa

The thickness and colour of the seed testa when taken as a criterion for the detection of the influence of the pest distribution on the different accessions revealed the seed testa to be thick for the accessions V98, V30, V2 and V61 (Table 17). All the other accessions recorded thin testa. Though no correlation could be worked out, the susceptible strains were seemed to have thin seed testa. While considering the colour of the seed testa, it was quite evident that colour had no direct influence on the pest distribution for the accessions of moderately and highly susceptible groups. But three of the accessions belonging to the moderately resistant group had light green seeds giving a clue that this light shade could be the cause for moderate resistance of the accessions.

5 2.C.III. Disposition of seeds in pods

Classification of the accessions according to the arrangement of seeds in the pods presented in Table 18 projects a variation in the nature of seed distribution for the different classes.

A loose arrangement of the seeds for the accessions belonging to the moderately resistant class and a moderately close packing of seeds was the result for the accessions under the moderately susceptible group. Four of the accessions out of the 5 classified under the highly susceptible group were seemed to have close packing of seeds in their pods. Reports by Srinivasan and Basheer (1961), Krishnaiah and Vijay (1975) and Lal et al. (1976) indicate a decreased rate of spread of the fruit and shoot borer L. orbonalis Guen in brinjal which they attributed to the hardness of the fruit skin and flesh They had observed compact seed arrangement which hindered larval entry into the fruits.

Results of the present investigation do not agree with the above finding as the moderately and highly susceptible accessions recorded a compact packing of the seeds within the pods. Besides, the arrangement of seeds in the moderately resistant accessions were contradictory to the former reports.

5.2.D Pubescence of the pods

Pubescence of the pods, which is one of the most important physical character associated with resistance was studied with an intention to know whether it had any direct influence on the level of pest incidence.

Categorisation of the different accessions into four on the basis of the counts of trichomes indicated 5 of the accessions to have a glabrous nature. These 5 were the members of different categories. A sparse spreading of the trichomes was observed for the accessions V61, V41, V96 and V12. The varieties V30, V13, V89 and V57 had pubescent nature. It was densely pubescent for V95 and V12.

A strong correlation between cotton hairiness and resistance to the leaf hopper on cotton varieties was reported by Parnel et al. (1949). They suggested the variety of cotton resistant to the leaf hopper to be hairy. Lukefehr et al. (1965) reported preference for oviposition on smooth leaves of cotton by the lepidopteran pests.

Resistance of the wheat variety to cereal leaf beetle, O. melanopus (L.) was attributed to pubescent character (Ringland and Everson, 1968). The number of eggs laid by gravid females of O. melanopus (L.) were reduced by greater density of pubescence, according to Schillinger and Gallun (1968). Another similar report was from Sambandam et al. (1969) where it was stated that the aphid A. gossypi (Glover) refused to settle on S. mamosum L. as the plants were densely pubescent with long hairs. Similar reports include the work by Brar and Sandhu (1975) on groundnut, Smith et al. (1975) on cotton, Cubson, 1976 on potato and Kowaleski and Robinson, 1977 on Cucumis.

Field evaluation by Quiros et al. (1977) revealed an increase in hair density in tomato plants to restrict the feeding activity of potato aphid, M. persicae (Sulz.). Field bean cultivars with glabrous pods were resistant to the attack by the pod borer, A. atkinsoni (Moore) as per Chakravarthy (1978). Chiang et al. (1988) found out that the spread of the trichomes in V. vexillata accounted for its resistance to the pod sucking bug, C. tomentosicollis (Stal.)

Results of the present investigation revealed the pubescent or glabrous nature of the pods to be not a criterion for the spread of the pest. Varieties of the moderately resistant group which had glabrous nature were V98 and V75. The varieties V100 and V1 categorised under the highly susceptible group were also glabrous.

These two gave a correct indication wherein glabrous nature would provide more access for the pest. But another member of this very same class i.e. V12 was observed to be densely pubescent. But V95, which appeared to be densely pubescent hails from the moderately resistant class. With these contrary results, it is clear that the distribution pattern of trichomes on pods is not a deciding factor for the pest distribution atleast in cowpea.

5.3. Biochemical components

Since the nutritive value of the host plant to insects feeding on them appears to play an important role in determining the susceptibility to the insect attack, the relation between different biochemical components of the plant like total sugars, amino acids, total nitrogen and crude protein were estimated. The conclusions which could be derived from the above study projects the effect of their presence on the pest spread.

5.3.A. Total sugars

Assay of total sugars in the different cowpea accessions is summarised in Table 20. Moderately resistant strains were with lower contents of total sugars. An increase was recorded for the moderately susceptible ones and the highly susceptible accessions had higher per cent of total sugars. It was seen that the per cent of pod damage in the accessions was positively correlated to the contents of total sugars in the pods (Table 21).

Relevant reports by several workers revealed high sugar content in plants to be related to the susceptibility to pests. Sugars acted as feeding stimulants and the larvae intensively fed on plant parts containing higher sugar contents (Knap, 1960; Macfoy, 1982). Singh et al. (1980) revealed the concentration of total sugars to be higher in the susceptible variety of sorghum to the shoot fly *A. soccata* (Rond.). Report by Macfoy et al. (1982) indicated a very low level of total sugars in resistant cowpea cultivars to the legume pod borer, *M. testulalis* (Geyer) than in susceptible varieties. The results of the present investigation corroborate with the above findings.

There are also reports by other scientists pointing out the development of resistance when the concentration of sugars exceeds a certain limit. Brett et al. (1965) attributes the development of resistance to pickle worm *D. nitidalis* (Stoll.) to be due to the increase in the concentration of D-glucose above 1% in squash varieties. Similar were the report by Jayaraj (1967a) from his screening trial in castor, Maltais and Auclair (1967) from pea varieties and Chhabra et al. (1981) from black gram.

5.3.B. Amino acids

The assay of amino acids in the different accessions resulted in variations among them (Table 20). Increase in the amino acid content was evidenced for the different accessions of the moderately susceptible group. A still higher increase in the amino acid content was detected for those accessions in the highly susceptible group, it being the maximum for V1.

Results of the correlation studies between the mean content of total amino acids in the pods and the per cent of pod damage indicated a high positive correlation between them. Accessions of the moderately resistant group possessed low amino acid content. This finding generally agrees with the observations by Auclair and Maltais (1950). They investigated the concentration of amino acids in the pea varieties susceptible to A. pisum (H.). Susceptible strains generally contained high concentration of amino acids than the resistant variety. Another report by Auclair et al. (1957) which points out the lower amino acid concentration in the pea plant sap to be an important component responsible for antibiosis in pea variety to infestation by pea aphid, A. pisum (H.), supports the present finding. Similar were the reports by Banepal and Hall (1967), Jayaraj (1967b) and Thirumurthi (1970) on crops like cauliflower, castor and sorghum respectively. Natarajan (1971) had attributed low quantity of amino acids in brinjal to confer resistance to the epilachna beetle. Sambandam and Chelliah (1972) detected low quantities of amino acids in varieties of C. callosus (Rottl.) resistant to the fruit fly, D. cucurbitae Coq

In contrast to the above results, Mehta (1971) could not detect any additive effect for amino acids in eliciting improved feeding responses from the boll worm, *E. fabia* Stoll. infesting cotton.

It is interesting to observe that the results of the present investigation correctly agree with the report by Macfoy *et al.* (1972). From an identical research work where the biochemical analysis of cowpea cultivars was carried out, a higher concentration of amino acids in the varieties susceptible to *M. testulalis* (Geyer) and a lower concentration in the resistant varieties was observed.

5.3.C Total nitrogen and crude protein

Assay of total nitrogen and crude protein in the cowpea accessions resulted in significant variations between them (Table 23). The concentration was minimum for V30, an accession under the moderately resistant group. The other members of this group also registered lower concentration when compared to the other two groups under study. An increasing trend observed for the members of highly susceptible group, was at its maximum in V57.

Very similar reports were detected with crude protein in different accessions (Table 23). Here too, the accession V30 had the least crude protein concentration and V57 had the highest concentration

Correlation coefficient between the mean per cent of total nitrogen and crude protein in the accessions and the pod damage by the pest, when worked out revealed a positive correlation between these two (Tables 24 and 25). It was clear from the data that higher nitrogen or crude protein in the pods favoured the pest distribution more and there was an increasing population. Those accessions with lesser concentration of total nitrogen and crude protein suffered less damage.

Reports by Evan (1938) suggests the rate of reproduction in the cabbage aphid B. brassicae (L.) to have correlation with the nitrogen and protein content of the host plant. Similar to the present findings were the reports by Sharma and Chatterji (1971) and Singh and Jotwani (1980). Sharma and Chatterji found the mean per cent of nitrogen to be significantly higher in the varieties of sorghum susceptible to C. zonellus (S.). According to Singh and Jotwani (1980), the susceptibility of sorghum variety to the shoot fly, A. soccata (Rond) was due to higher per cent of nitrogen in the leaves and leaf sheath. Another supporting data for the present result was from Macfoy et al. (1982). Investigations similar to the present study record cowpea varieties resistant to the pod borer, M. testulalis (Geyer) to have lower quantities of total nitrogen and protein. Patriquin et al. (1988) reported the facundity of aphids in faba bean to be proportional to the soluble nitrogen content of Phloem. It was found to increase when the plants were given nitrogenous fertilizers.

In the present studies, it has been possible to rate the accession V30 to be the most moderately resistant and V100 to be the most susceptible accession to infestation by *M. testulalis* (Geyer). The dominant mechanism of resistance in this accession has been identified to be antibiosis due to certain biophysical and biochemical factors. There is considerable scope for the utilisation of this moderately resistant variety in breeding projects for the development of promising genotypes of cowpea with multiple resistance and with good agronomic attributes.

Summary

6. SUMMARY

In Kerala, considerable loss are caused to cowpea on account of infestation by the pod borer particularly M. testulalis (Geyer). Insecticidal control of the pest is not advisable due to the hazards from terminal residues. Screening of the germplasm reserves consisting of 100 varieties of cowpea with reference to their susceptibility to M. testulalis (Geyer) under natural conditions was hence conducted. The varieties were then categorised into different clustures on the basis of their innate resistance traits. The study of the biophysical and biochemical basis of resistance to M. testulalis (Geyer) was also envisaged to understand the resistance mechanism.

Field screening of the accessions revealed high variability in respect of their susceptibility to the pod borer infestation. Of the 100 accessions screened, the flowers of 55 varieties seemed to have heavy infestation by the larvae which were categorised under the highly susceptible group, 28 as moderately susceptible and the rest seventeen accessions as moderately resistant. While considering the pod damage, the range of susceptibility was high for 56 varieties, moderate for 27 varieties and the rest seventeen were moderately resistant.

This study rules out the chance of any of the 100 varieties screened to be resistant to this pest. But laboratory observations have identified the accessions V30 as the most moderately resistant type and V100 as the most susceptible one.

A low per cent of larval survival on the flowers and pods was recorded for all the accessions under the moderately resistant group. But, in the moderately susceptible group, the survival was higher. V100 provided the ideal condition for the larvae and V30 identified itself to be the most unsuitable host. V30 exhibited antibiosis mainly in the form of larval mortality.

A wide variation in the developmental period of the pest was recorded on different cowpea accessions. Among the highly susceptible accessions, V100 seemed to have a positive effect on the pest with a minimum duration of development Quite contrary was the result with those larvae reared on moderately resistant strains, exhibiting prolongation of larval duration. A significant variation in the adult emergence was observed on different cowpea accessions. The susceptible accessions favoured high adult emergence trends whereas the resistant ones proved to be detrimental to the pest.

While evaluating the influence of cowpea accessions on the sex -ratio, a lowered female proportion in the resistant strains and a higher proportion in the susceptible ones was observed. This was believed to be due to the antibiotic effect of the host on the pod borer. The might have resulted in the selective mortality of would be females in the resistant types due to nutritional constraints.

The fecundity of the female moths was found to be higher in the moderately and highly susceptible accessions compared to the moderately resistant ones. Here antibiosis might have been responsible for the stimulation of reproductive potential of the insect when reared on its favoured hosts.

An evaluation of the effect of different biophysical factors on the pest revealed no significant correlation between pod wall thickness and pod borer infestation. But the extent of flower damage was correlated positively with the mean length of flower stalks. The configuration of calyx and the disposition of corolla had a direct influence on the pest distribution. Pubescence of the pods, disposition of seeds and nature of the seed testa did not influence the spread of the pest population.

A screening of the influence of different biochemical components on the pest spread indicated that sugars acted as feeding stimulants for the larvae and the concentration of total sugars was higher in the susceptible varieties. A similar correlation was worked out between the amino acid content in the pods and the level of pest incidence. It was understood that the higher nitrogen and crude protein levels in the pods favoured the pest distribution more. Those accessions with lesser concentration of total nitrogen and crude protein suffered less damage.

Thus the accession V30 was identified to be the most moderately resistant and V100 the most susceptible to infestation by the pod borer, *M. testulalis* (Geyer) The dominant mechanism of resistance has been identified to be antibiosis due to certain biophysical and biochemical factors.

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*Originals not seen

HOST RESISTANCE IN COWPEA (*Vigna unguiculata* (L.) Walp) TO THE POD BORER *Maruca testulalis* (Geyer)

(PYRALIDAE : LEPIDOPTERA)

By

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation on the host resistance in cowpea (*Vigna unguiculata* (L.) Walp) to the pod borer *Maruca testulalis* (Geyer) was carried out by screening 100 varieties of cowpea during 1990-91. These were classified into highly susceptible, moderately susceptible and moderately resistant classes. This study rules out the chance of any of the varieties screened to be resistant to this particular pest.

Selected accessions from the three different classes based on the field evaluation, were subjected to artificial infestation by the first instar larvae of *M. testulalis* on caged plants in the green house. Here too, the susceptibility spectrum was found to be similar to the trend observed in the field trial. The accession V30 was identified to be the most moderately resistant type and V100 as the most susceptible one.

In the studies on antibiosis it was found that the larvae reared on moderately resistant type took longer durations of development as compared to the susceptible ones. The larval survival as well as the adult emergence was lower in the resistant types The highly susceptible accessions produced more females than the resistant lines. The fecundity of F_1 females was adversely affected when the larvae were reared on the moderately resistant accessions.

Among the biophysical components, though the pod wall thickness and pubescence of the pods did not show any correlation with the level of borer infestation, the length of flower stalks, disposition of corolla, calyx and seeds and the nature of seed testa, had a positive influence on its distribution.

Positive correlations were also detected between the mean percentage of total sugars, crude protein, amino acids and nitrogen in the pods on the one hand and pod damage on the other.