MECHANISMS OF RESISTANCE TO *Helicoverpa armigera* (Hubner) IN PIGEONPEA [*Cajanus cajan* (L.) Millsp.]

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CERTIFICATE

This is to certify that the thesis entitled **"MECHANISMS OF RESISTANCE TO *Helicoverpa armigera* (Hubner) IN PIGEONPEA [*Cajanus cajan* (L.) Millsp.]"** submitted in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mrs. D. ANITHA KUMARI** under our guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.

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(D. ANITHA KUMARI)

DECLARATION

I, **D. ANITHA KUMARI**, hereby declare that the thesis entitled **"MECHANISMS OF RESISTANCE TO *Helicoverpa armigera* (Hubner) IN PIGEONPEA [*Cajanus cajan* (L.) Millsp.]"** submitted to Acharya N.G. Ranga Agricultural University for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** is a result of original research work done by me. I also declare that the material contained in this thesis or part there of has not been published earlier in any manner.

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ABSTRACT

The present investigations on **"MECHANISMS OF RESISTANCE TO *Helicoverpa armigera* (Hubner) IN PIGEONPEA [*Cajanus cajan* (L.) Millsp.]"** were undertaken under laboratory and field conditions at International Crops Research Institute For Semi Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India during 2000 – 2001 and 2001-2002 cropping seasons.

Twelve germplasm accessions of pigeonpea were evaluated for stability of resistance to *H. armigera* under natural infestation. Stability of resistance was measured by regression analysis of the data for pod damage and grain yield. Amongst the 12 genotypes tested, lowest pod damage was recorded in ICPL 187-1 (39%) followed by ICPL 332, ICPL 84060, and ICPL 88039 (47–53%). For ICPL 84060, the regression (b) value was <1 and residual mean square equal to zero. However the pod damage percentage was not stable over the seasons.

Mechanisms of resistance (antixenosis for oviposition, antibiosis and tolerance) to *H. armigera* in 12 pigeonpea genotypes were studied in laboratory and field conditions. Oviposition studies under no-choice, dual-choice and multi-choice conditions revealed that among the medium to long duration genotypes ICPL 87119 and ICP 7035 were preferred for oviposition compared with ICPL 84060 and ICPL 332 (resistance check). Among the short-duration genotypes, the susceptible check ICPL 87 was preferred most, followed by ICPL 87091, ICP 7203-1, ICPL 88039, and ICPL 98001.

Reduced larval and pupal weights, and prolonged larval and pupal development was recorded on artificial diet impregnated with lyophilised leaves and pods of ICPL 332, ICPL 84060, ICP 7035, ICPL 187-1, ICPL 88039 and ICP 7203-1 as compared to the susceptible genotypes ICPL 87 and ICPL 87091 indicating the presence of antibiosis component of resistance to *H. armigera* in these genotypes.

Five morphologically distinct trichomes: Type A, B, C, D and E were identified on pods and calyxes of the 12 pigeonpea genotypes studied. Type A and B trichomes were present in greater density in flowers and pods. In case of pods, Type D trichomes were present in greater numbers compared to Type A. High density of nonglandular trichomes (Type A and Type B) might contribute to the larval mortality in the resistant genotypes (ICPL 84060, ICPL 87119, ICPL 88039, ICP 7203-1, ICPL 187-1 and T 21).

The pod surface extracts of ICPL 87 and ICPL 332 stimulated feeding by the third, fourth and fifth instar larvae of *H. armigera* when presented at pod surface equivalents. The attractions of *H. armigera* larvae to ICPL 87 and ICPL 332 plant extracts appears to result from chemical compounds present in the extracts. Nutritionally important constituents of a host plant play a significant role in the feeding behaviour of phytophagous insects. The levels of Potassium and Phosphorus were low in resistant genotypes such as ICPL 332, ICPL 84060, ICP 7035 and ICPL 187-1, but high in susceptible check ICPL 87. Higher protein content was observed in resistant geneotypes ICPL 332, ICP 7035 and ICPL 84060 as compared to susceptible check ICPL 87.

The loss in grain yield due to *H. armigera* in 12 pigeonpea genotypes under protected and unprotected field conditions indicated the presence of tolerance mechanism of resistance in pigeonpea genotypes. Reduction in grain yield was lowest in the resistant check ICPL 332, followed by ICPL 84060, ICPL 87 and ICPL 87119 indicating tolerance to pod borer damage in these genotypes.

Chapter I

INTRODUCTION

CHAPTER – I

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the major pulse grain legumes grown between 30^0N and 30^0S in the semi arid tropics (Nene *et al.*, 1990). It is an important source of high quality dietary protein and is mostly consumed in the form of split pulse. It plays a significant role in the nutritional security of the overwhelming majority of vegetarian people of the Indian Sub-Continent. More than 150 insect species feed on this crop, of which pod borer, *Helicoverpa armigera* (Hubner) is the most damaging pest worldwide (Shanower *et al.*, 1999). The pest can cause complete crop loss (Reed and Lateef, 1990). *H. armigera* damage is particularly severe in indeterminate plant types than in determinate ones (Reed and Lateef, 1990). Over the past decade, three outbreaks of this pest were recorded, the latest being in 1997 in Gulburga, which is known as the pulse bowl of Karnataka. *H. armigera* causes 50 to 60% grain loss in pigeonpea. During 1997-98, the pigeonpea suffered a complete loss due to *H. armigera* (Puri, 1998). On an average, pod borer caused 90 – 100% yield loss in 1992-93 and 1997-98 (Yelshetty and Gowda, 1998). In the semi-arid tropics, pod borer cause an estimated loss of US$325 millions annually (ICRISAT, 1999).

Pigeonpea is mainly grown during the rainy season. Traditionally grown plant types are long-duration (180 - 300 days to maturity), and the plants can also be maintained as perennials (Nene *et al.*, 1990). In the recent years, there is increasing emphasis on short-duration cultivars, in which the first flush of pods can

mature in 90 to 120 days (Chauhan, 1990). Such cultivars are grown in rotation with wheat and other winter crops in northern (Singh., 1996; Dahiya *et al.*, 2001), central and peninsular India (Nam *et al.*, 1993). Pigeonpea is grown on relatively poor soils, and has the potential to provide upto three crops per year (Rangarao and Shanower, 1999). In India, pigeonpea is grown on 3.2 million hectares with an annual production of 2.48 million tonnes and accounts for 85 to 90% of the worlds area under pigeonpea (FAO, 2001). Pigeonpea yields have remained stagnant for the past three to four decades, largely due to insect pest damage.

H. armigera has a wide host range, and feeds on more than 300 plant species, of which pigeonpea is highly preferred. Prior to 1975, less than 20% farmers used insecticides on pigeonpea. However, 1993 onwards, there is a widespread adoption of insecticides for pest management on pigeonpea. Due to widespread use of insecticides, it has developed considerable levels of resistance to conventional insecticides, including synthetic pyrethriods (Armes *et al.*,1992). Natural enemy activity on *H. armigera* in pigeonpea is quite low as compared to that on other crops such as sorghum (Bhatnagar *et al.*, 1980). As a result, there is greater survival of the insect on pigeonpea and results in heavy loss in grain yield.

During the course of evolution, plants acquire several defense mechanisms against insect pests. The major mechanisms are antixenosis (non-preference), antibiosis, tolerance, and escape (Painter, 1951). These mechanisms are operational within the plant through different component traits. Using specific assays to monitor the effects of particular physical and chemical characteristics on insect behaviour and physiology, resistance has been differentiated in terms of

antixenosis, antibiosis and tolerance. To date, more antibiosis than antixenosis or tolerance has been reported in legume crops (Clement *et al.*, 1994).

Insecticide application for controlling *H. armigera* is uneconomical under subsistence farming, and is largely beyond the means of resource for poor farmers Therefore, host plant resistance (HPR) assumes a pivotal role in controlling *H. armigera* damage either alone or in combination with other methods of control. HPR is an important component of integrated pest management (IPM), and is well suited to the environmental conditions of the semi-arid tropics. Host plant resistance avoids environmental pollution and is compatible with natural control measures Besides, it integrates effectively with other pest control tactics, and involves no additional cost to the farmer It has been documented that for each $1 invested in plant resistance, farmers have realized a $300 return (Robinson, 1996).

The identification and utilization of cultivars resistant/tolerant to *H. armigera* would have a number of advantages, particularly for a relatively low-value crop such as pigeonpea. Screening of germplasm (more than 14,000 pigeonpea accessions) for resistance to *H. armigera* has revealed very low levels of resistance to this pest (Reed and Lateef, 1990). Several lines of pigeonpea such as ICPL 7703, ICPL 332, ICPL 87088, ICPL 84060 and ICPL 87089 with low to moderate levels of resistance have been identified (Lateef, 1992; Sachan, 1992).

Among the pigeonpea cultivars, ICP 7203-1 and ICPL 84060 suffered 7% damage by *H. armigera* compared to 16% damage on ICPL 187-1, 30% on ICPL 332, and 76% on ICPL 87 (ICRISAT, 1999). However, these germplasm lines have not been characterized for diversity and mechanisms of resistance to this insect Although several genotypes with resistance to *H. armigera* have been

reported, little progress has been made in incorporating resistance into cultivars with acceptable grain yield and quality. Wild relatives of *Cajanus cajan* are also a potentially valuable source of germplasm for improving resistance or tolerance to insect pests in pigeonpea (Pundhir and Singh, 1987).

The larvae of *H. armigera* feed on leaves, growing points, flowers and pods. When periods of *H. armigera* activity occur during vegetative stages, significant amount of leaf feeding can occur. However, once flowering commences, feeding occurs preferentially on reproductive plant parts. The usual sequence followed by a *H. armigera* on pigeonpea appears to be for moth to lay eggs on flowers, young pods or leaves in the upper part of the crop.

Yoshida and Shanower (2000) reported that *H.armigera* grows slowly on artificial diet containing *Cajanus scarabaeoides* pod powder than *C. cajan* pod powder due to antifeedant or growth inhibiting compounds and/ or poorer nutritional quality of the wild species.

Knowledge of the resistance mechanisms and associated factors involved is essential for effective utilization of sources of resistance in the breeding programs. Despite large scale screening of the germplasm, it has been felt that there is a scope for substantially improving HPR in pigeonpea to *H. armigera,* through a comprehensive understanding of the mechanisms by which the pod borer is either attracted to or repelled from pigeonpea.

The behaviour of *H. armigera* is influenced by various physical, chemical, and visual stimuli. Some possible physical deterrents may be pod wall thickness and hairs on the pod. Trichomes and their extracts and/or pod surface

chemicals may also provide some protection against *H. armigera* feeding damage. Acetone extracts of *C. scarabaeoides* pod surface include a weak, but significant feeding inhibitor (Romeis, 1997).

Cajanus scarabaeoides has been reported to be highly resistant to *H. armigera* (Lateef *et al.*, 1981; Saxena *et al.*, 1990; Shanower *et al.*, 1997). Larvae feeding on flowers and green pods of *C. scarabaeoides* grow slower, take longer to pupate, and form smaller pupae than those fed on *C. cajan* (Lateef *et al.*, 1981; Shanower *et al.*, 1997). A high density of pod surface trichomes, a tough pod wall, and differences in the structure of pod tissue may contribute to the poorer growth of *H. armigera* compared with *C. cajan* (Lateef *et al.*, 1981; Romeis *et al.*, 1999a). In addition to physical factors, chemicals in or on the pods may also contribute to *C. scarabaeoides* resistance to *H. armigera*. Once the particular mechanisms by which *H. armigera* is discouraged from pigeonpea are identified, systematic attempts can be made to incorporate these characteristics into high yielding cultivars. To elucidate some of the mechanisms involved in *H. armigera* resistance in pigeonpea, the present investigations were undertaken.

1. To evaluate the pigeonpea genotypes for the levels and stability of resistance to *H. armigera*.

2. To characterize the sources of resistance for oviposition, non-preference, antibiosis and tolerance components of resistance.

3. To quantify the relative contribution of different components towards resistance to the pod borer.

Chapter II

REVIEW OF LITERATURE

CHAPTER – II

REVIEW OF LITERATURE

Pigeonpea is an important grain legume endowed with several unique characteristics, finds an important place under subsistence farming systems in the semi-arid tropics. Pigeonpea seed protein content containing about 2% compares well with that of other important grain legumes (Nene *et al.*, 1990). Insect pests feeding on flowers and pods cause the severe damage of which *Helicoverpa armigera* (Hubner) is the most important world wide. The larvae feed on buds, flowers, and pods of pigeonpea, and when these are not available, they feed on young leaves (Reed *et al.*, 1989).

Most of the screening for host plant resistance to *H. amigera* has been carried out at ICRISAT (Lateef and Pimbert, 1990). In general, determinate genotypes show greater susceptibility to pod damage by *H. amigera* than indeterminate types (Kushwaha and Malik 1987; Reed and Lateef, 1990) One of the reasons for high susceptibility of determinate type genotype to *H. armigera* may be due to cluster type of flowering making it easier for larvae to move from one pod to another. Within short duration determinate types, ICPL 289 and H 81-95 (Kushwaha and Malik, 1987) have shown less susceptibility to pod borer (Dahiya *et al.*, 2001). Among the medium- duration types, most of genotypes have indeterminate growth habit, and genotypes ICP – 909 – EB, PPE – 45-2, ICP 1811-E3, ICP 1903 – E, (ICPL 332), and ICP 10466 – E3 have shown less susceptibility to pod borer (Lateef and Pimbert, 1990). Short duration varieties (150 days) are safer from pod borer than extra early varieties (Singh, 1996).

Even though various chemical control measures have been devised to minimize the losses caused by pod borer, this pest has developed resistance to insecticides. Further, even from ecological and economical view point, cultivars having resistance to the pest is the most important component of IPM. It has been documented that with each $1 invested in plant resistance, farmers have realized returns of $300 (Robinson, 1996).

The eggs of *H. armigera* are nearly spherical with a flattened base, and are laid singly. The larva leaves the plant in 3 weeks or less, and bores into the soil to a depth of 1.5 to 2.5 cm, where it pupates. The pupa is 14 to 18 mm long, mahogany, brown, smooth surface, and rounded both anteriorily and posteriorly, with two taperings and parallel spines at the posterior tip. The medium sized brown moths emerge from the soil in about 2 weeks. Adult females are larger and stouter than males. Female moths live longer than males. The life cycle will be completed in little more than a month. As each female can lay more than 1000 eggs, infestations can increase very rapidly (Reed *et al.*, 1989). More than 3000 eggs per female have been reported, though fecundity in the range of 1000 -2000 is common (Reed, 1965). In India, three species of *Helicoverpa*, *H. armigera*, *H. peltigera* Schiff. and *H. assulta* Guenee have been recorded, of which *H. armigera* is the most important. *H. armigera* passes through four generations in Punjab. One on chickpea during March, two on tomato from end of March to May, and one on maize and tomato between July to August (Singh and Singh, 1975). Bhatnagar (1980) reported seven to eight generations of *H. armigera* in Andhra Pradesh. Oviposition usually starts in early June, with the onset of pre-monsoon showers. Adults possibly emerge from the diapausing pupae and from the larvae on summer crops and weeds. The pre-oviposition period range from 1 to 4 days. Oviposition period last 2 to 5

days, and post oviposition period is 1 to 2 days (Patel *et. al.*, 1968; Singh and Singh, 1975).

The preferred host plants for oviposition by *H. armigera* were studied by Vijayakumar and Jayaraj (1982) and found to be in descending order as pigeonpea > field bean > chickpea > tomato > cotton > chillies > mungbean > sorghum. Reddy (1973) and Loganathan (1981) reported that pigeonpea was the preferred host for oviposition. The feeding preference descending order was pigeonpea > field bean > cotton > sunflower > sorghum > chickpea > mungbean > urd bean > and tomato. The larval period was maximum in tomato and minimum in pigeonpea and ranged from 17 to 20 days (Dhandapani and Balasubramanian, 1980). The pupal stage ranged from 10.5 to 13.6, days being minimum on pigeonpea and maximum on sorghum, maize and sunflower.

There are several factors associated with the population build up of *H. armigera*. It is speculated that an increase in irrigation in south India has led to availability of host plants throughout the dry season, and resulted in subsequent increase in pest population (Reed and Pawar, 1981). *H. armigera* undergoes facultative diapause during December to February in North India. As a result, the pupal period lasts for more than 100 days. The prolonged pupal period leads to the low population build up during last leg of winter, season resulting in the non-availability of larval parasitoids.

H. armigera is a multiple generation pest with a wide host range. Therefore, the population may build up on one crop, and then move to at another in large numbers. Since the population increase may not occur within the crop, high levels of resistance are required if its populations are to be stabilized below the

economic threshold level Therefore, it requires a peruse methodology to recover lines with diverse mechanisms of resistance. The ability of ovipositing females to locate and utilize a wide range of hosts from diverse plant families is one of the factors contributing to the pest status of this moth (Zalucki *et al.*, 1986; Fitt, 1989) Learning is of fundamental importance in understanding the host selection behaviour of *H. armigera.* Laboratory evidence determining the relative preference of *H. armigera* for different host species does not account for the effect of experience, which can significantly alter host selection behaviour In a field situation, the preference of *H. armigera* for different host species may be affected by the prevalence and abundance of these hosts. With the increasing resistance that *H.armigera* is exhibiting towards wide range of pesticides (Mc. Caffery *et al.*, 1991), the necessity to design future pest management strategies to control this moth, becomes more apparent. Current research into the use of volatiles for monitoring and trapping, the use of trap crop and resistant crop varieties for controlling this moth all require a detailed understanding of host selection behaviour.

Sharma *et al.* (1989) have studied the effect of different food plants viz., gram, red gram, cotton, tomato, chilli, sorghum and maize on the growth and development of *H. armigera* On the basis of larval period, pupal period, pupal weight, % pupae formed, % moths emerged and number of eggs laid, gram was found to be the most favourable food, and sorghum the least.

Different plant parts within the same host may also differ in their suitability for *H. armigera.* Hmimina (1988) found that larval growth was faster on cotton flowers, buds than on cotton leaves, potato leaves, tomato fruit, maize cobs or

synthetic diet and no larvae survived on tomato leaves. Young larvae feed on sorghum flowers but older larvae prefer developing grains (Roome, 1975).

In pigeonpea, eggs are laid on flower buds and young pods, while in chickpea, the eggs are usually deposited on foliage (Rangarao and Shanower, 1999). The young larvae of *H. armigera* usually eat some or all of its egg shell before feeding on the plant. It wanders about nibbling various parts of the plant until it finds a flower bud or flower. Temperature and the host plant affects the development of the larva considerably.

The larvae of *H. armigera* reared on pigeonpea pods pass through five or six instars under laboratory conditions at a constant temperature of 26+10°C The head capsule width data supported Dyars hypothesis indicating that the five or six larval instars observed in *H. armigera* are fairly constant (Bilapate *et al.*, 1988). The larval duration varied from 8 to 12 days in the Punjab, India (Singh and Singh, 1975). The fully grown larva leaves the plant, sometimes by dropping to the ground, and burrows into the soil to a depth of 2.5 to 17.5 cm where it pupates (Pearson and Darling, 1958).

Much of the screening for host plant resistance (HPR) in pigeonpea to *H. armigera* has been carried out at ICRISAT from the mid-1970s to the early 1990s (Lateef and Pimbert, 1990). Genotypes showing consistent differences in extent of pod damage have been identified. In general, genotypes with a determinate growth habit show greater susceptibility to pod damage by *H. armigera* than indeterminate types (Kushwaha and Malik, 1987; Reed and Lateef, 1990). One reason for this may be that the cluster of flower pods at the end of the branch in determinate types simply makes it easier for larvae to move from one pod to another. Within short-

duration determinate types, genotypes ICPL 289 and H 81-95 have shown less susceptibility to pod borer (Kushwaha and Malik, 1987). Among short-duration indeterminate types, ICPL 88039 has proven to be less susceptible under farmers' field conditions (Dahiya *et al.*, 2002). Among medium-duration types, most of which have indeterminate growth habit, ICP 909-EB, PPE 45-2, ICP 1811-E3, ICP 1903-E1 (ICPL 332), and ICP 10466-E3 have shown less susceptibility (Lateef and Pimbert, 1990), been released primarily on the basis of its resistance to *H. armigera.* However, this variety did not prove to be very popular because of its small pod and seed size.

Keeping in view the polyphagous nature of the insect, development of pigeonpea varieties resistant to *H. armigera* appears to be complex problem. Some pigeonpea varieties with reasonable tolerance to the pod borer are JA 4, GT 100 and Co 6. The bulk of progenies of Pusa 971 based on less than 25% as prime defence can be useful in integrated pest management strategy (Dua *et al.*, 2002). Varieties with high degree of resistance to pod borer need to be developed for commercial cultivation.

2.1 STABILITY OF RESISTANCE TO *H. armigera* IN PIGEONPEA

Stability of resistance is one of the desirable traits of a genotype to be used as a donor parent for incorporating resistance. Although, number of sources of resistance (less susceptibility) to *H. armigera* have been reported, stability of resistance across locations and/or seasons is not known. Information on genotype x environment (G x E) interaction for *H. armigera* resistance is limited. Therefore, the present studies were planned to collect the information about stability of resistance

to *H. armigera* in pigeonpea in known sources of resistance available in breeding program and genetic resource collection at ICRISAT.

Several approaches have been made to extract parameters of genotypic stability from genotype x environmental interactions. Finlay and Wilkinson (1963) utilized a regression technique proposed by Yates and Cochran (1938) to measure "stability indexes" of barley varieties. They considered linear regression as a measure of stability (i.e., a genotype is more stable with a slope of more than one). Eberhart and Russell (1966) defined a stable genotype is one having a slope equal to one and a deviation from regression equal to zero. This approach has been extensively used by plant breeders (Reich and Atkins 1970; Kofoid *et al.*, 1978; and Virk *et al.*, 1985). Breese (1969), Samuel *et al.*, (1978), and Pethani and Kapoor (1985) emphasized that the linear regression should be regarded as a measure of the response of a particular genotype, whereas the deviation around the regression line should be considered as a measure of stability, genotypes with the lowest deviations being the most stable and vice versa.

Eberhart and Russell (1966) reported that the deviation from regression, a second stability parameter, appears very important, as the genotype x environment (linear) sum of squares was not a very large portion of the genotype x environment interaction.

According to Comstock and Moll (1963), a cultivar must not only yield well in its area of initial selection, but ideally it also must maintain a high yield level in many environments within its intended area of production.

Singh *et al.* (1988) studied phenological traits in chickpea and analyzed them for stability following Eberhart and Russell (1966) and indicated the importance of phenological traits for production stability in chickpea.

Dahiya and Singh (1993) studied genotype x environment interaction for yield and its components in 29 pigeonpea lines in 3 environments following Eberhart and Russell (1966). Six genotypes were stable for yield as they exhibited high mean performance, a unit regression coefficient and low magnitude of deviation from regression.

Sharma and Lopez (1990) studied stability of resistance in sorghum to *Calocoris angustatis* (Hemiptera: Miridae) and concluded that the environmental conditions play an important role in determining the interaction between the insects and the host plant.

Singh and Singh (1995) reported positive and significant correlation between the mean of the genotypes and responsiveness to different environments for number of pods per plant, 100-grain weight and single plant yield in chickpea and indicated that the genotypes with high mean were in general, better responsive to favourable environments. There was lack of general association between stability of yield and its components, which calls for cautious selection of genotypes based on yield alone.

Singh and Singh (1991), Singh *et al.* (1994) and Singh *et al.* (1995) studied stability of yield and its components in chickpea and selected genotypes with high mean, unit regression slope and a non-significant deviation from regression as the measure for selecting promising genotypes for stability of yield. But in case of

pod borer resistance, genotypes with lowest damage, ORS (Overall resistance score) and PDS (Pod damage score), unit regression slope and non-significant deviation from regression were stable and resistant to *H. armigera.*

2.2 MECHANISMS OF RESISTANCE TO *H. armigera* IN PIGEONPEA

2.2.1 Antixenosis for oviposition

The physiological state of an insect is a product of numerous interacting variables, including age, feeding status, mated status and egg load (Fitt, 1986, Courtney and Kibota, 1990). Females with higher egg load may be less discriminating and more accepting of low ranking host plants (Minkenberg *et al.*, 1992; Prokopy *et al.*, 1994).

Mustapha *et al.*, (1998) examined the effect of age specific fecundity, mated status and egg load on host plant selection by *H. armigera* under laboratory conditions. The physiological state of a female moth (number of mature eggs produced) greatly influences her host plant specificity and propensity to oviposition motivation. Female moths were less discriminating against cowpea a low-ranked host relative to maize (a high ranked host) by the egg load increased. Increased egg load led to greater propensity to oviposit on both cowpea and maize. Distribution of the eggs by the mated females peaked shortly after mating, and declined steadily thereafter until death. Oviposition in *H. armigera* usually starts some hours after dusk, initially alternating with feeding, and later becoming the predominant activity until soon after midnight (Pearson and Darling, 1958). Moths are highly selective in

their choice of host plant, and / or suitable conditions of development (Hardwick, 1965)

According to Roome (1975) *H. armigera* oviposit freely in captivity even on unsuitable substrates The preference of this insect to a particular genotype, shown by laying more eggs, indicates the presence of physiological cues which trigger oviposition. These cues may be visual as well as chemical (Schoonhoven, 1990).

On pigeonpea, most of the eggs are laid on flowers and flower buds, and sparingly on the leaves mostly during the vegetative phase of the host On chickpea the eggs are laid on the leaves, mostly on the underside, and on the plant tissues when the plants are very small In contrast to other hosts, oviposition on chickpea declines with the onset of flowering (King, 1994).

Butter and Singh (1996) studied the ovipositional response of *H. armigera* on different cotton varieties under caged conditions Maximum oviposition was recorded on LH 900 - *Gossypium hirsutum* and minimum on G 27 *G. arboreum*. Oviposition in *general* was low on arboreum cottons as compared to hirsutum. Of the number of factors found to affect oviposition, the trichome length on the upper surface of leaf, rather than the density, was positively correlated Oviposition was maximum during April, and was higher on leaves rather than on other plant parts.

Sison *et al.*, (1993) conducted oviposition preference experiments under choice and no-choice conditions with 6 pigeonpea genotypes Among these, ICPL 87 had the highest number of eggs (29.2 ± 3.49) in the choice test, more than

twice the number on ICPL 88023 and ICPL 86015, and almost six times as many as on ICPL 87101 which had the lowest number of eggs In no-choice test medium number of eggs were laid on ICPL 87 and lowest on ICPL 86005 (87 3± 49 63) and ICPL 87101 (52 8±49 63)

Venugopal Rao *et al*, (1991), studied the distribution of eggs and larvae of *H. armigera* on ICPL 270, ICPL 332, ICPL 84060, and LRG 30 They observed that egg laying and larval incidence was significantly higher in ICPL 270 compared with LRG 30, ICPL 332 and ICPL 84060 The larval population was significantly more on top leaves, flowers and pods compared with the middle and bottom parts Among the vegetative and reproductive parts, egg laying was quite high on floral parts and new pods as compared to foliage

Of the six medium-duration pigeonpea genotypes (ICP 11964, ICP 1903, ICPL 84060, ICPL 87088, ICPL 87089 and ICP 1691) tested for *H. armigera* resistance at ICRISAT in 1991, egg and larval counts were lower on borer resistant lines compared to the borer susceptible cultivar, ICP 1691 Ovipositional non-preference was also confirmed under laboratory conditions (ICRISAT, 1991)

No eggs of *H. armigera* were recorded on *C. scarabaeoides* (ICPW accession nos 68, 90, 94, 116,125,130,137,141,152,278,280,281 and *Atylosia scarabaeoides* set –1), *A. cajanifolia* and *A sericeus* *Rhyncosia bracteata* and *A.albicans* were as much preferred for oviposition as the cultivated pigeonpeas Among the pigeonpea cultivars, there were only 12 eggs per 10 inflorescences on ICPL 332 compared to 29 on ICPL 84060, 39 on ICPL 187-1, 43 on ICP 7203-1 and 69 on ICPL 87 in the first observation In the second observation there were 2 to 7

eggs per 10 inflorescences on ICPL 1871, ICPL 332, ICPL 84060 and ICP 7203-1 compared to 23 eggs on ICPL 87 (Sharma *et al.*, 2001).

Lakshmipathi (2000) conducted studies on ovipositional preference by *H armigera* flower colour in pigeonpea. It was found that the number of eggs laid were significantly higher on the yellow flowers compared to red.

2.2.2 Antibiosis mechanism of resistance to *H. armigera*

Antibiosis is one of the important resistance mechanisms in plants to insects by Painter (1951). The effects of antibiosis may be reduction in size, weight, fecundity, abnormal length of life, and increased mortality of insects (Owens, 1975). Dodia and Patel (1994) studied the biology of the *H. armigera* on two resistant (ICPL 270 and ICPL 84060) and one susceptible (BDN 2) pigeonpea varieties under controlled temperatures. The observations showed that the larval and pupal mass of larvae fed on developing pods of resistant varieties were significantly lower and the duration of both the stages were longer than the larvae fed on the susceptible variety. The larval mortality remained high, and larval pupation, adult emergence, fecundity and growth index were adversely affected.

Five short medium-duration desi (small seeded) and 5 medium – long duration Kabuli (large seeded) chickpea genotypes were screened in the laboratory for antibiosis to *H. armigera* by Sison *et al.*, (1996). Larvae reared on either chickpea leaves or on pods containing green seeds showed significant variation among the desi genotypes for pupal weight and larval survival. Pupae resulting from larvae reared on either pods or leaves of ICCV 7 weighed substantially less than the larvae reared on Annegiri and ICC 3137. Pupae of larvae reared on leaves

of ICC 506 weighed substantially less than those reared on ICC 3137. There was no variation in the measured parameters for the larvae reared on the kabuli chickpea genotypes.

The feeding and food selection behaviour of different instars of the pod borer in response to choices between the cultivated and wild species of *Cajanus* was studied by Green *et al.* (2002). First and second instars fed on a cultivated variety of *C. cajan* in preference to *C. scarbaeoides*, and on flowers of *C. cajan* rather on pods or leaves of *C. cajan*. Young larvae (first- and second-instars) congregate inside flowers of cultivated variety as they are vulnerable to desiccation and predation. Later instars (third to fifth) prefer to feed on pods due to changes in the nutritional requirements across the instars. Older larvae of lepidoptera have increased appetitive behaviour (Raubenheimer and Barton, 2000) and need more protein (Simpson *et al.*, 1988).

Helicoverpa armigera larvae fed on artificial diets containing powder from ground seeds of resistant and susceptible pigeonpea genotypes indicated that seed coat from brown coloured seeds had an antibiotic effect on the larvae. Most larvae that were fed on the diets containing seed coats died, although a few survived for over 70 days. The white seeded genotypes showed least antibiosis, confirming field observations that most of these genotypes were susceptible to *H. armigera* (ICRISAT, 1985).

Lateef *et al.* (1981) studied the life cycle of *H. armigera* on *scarabaeoides*, *sericea* and *cajan* (ICP 1). It was found that the larvae grew more slowly on *Atylosia* spp. took longer to pupate, formed smaller pupae, and these adults laid few eggs. The pod walls of *A. scarabaeoides* are relatively tough, and

under field conditions, the pod borer damage is often limited to scarification of the pod surface such that seeds are left intact. Developing pods of *C. scarabaeoides* are devoid of glandular hairs and have lignified cells just below the epidermis, suggesting that this species also has a mechanical type of resistance in addition to antibiosis.

The antibiotic effects of flowers of *Cajanus scarbaeoides, C.cajanifolus, C . reticulatus, C. sericeus* F_1 *(C. scarabaeoides x C. cajan)* and cultivated pigeonpea (T15 – 15) on the biology of the *H. armigera* were studied by Dodia *et al.* (1996). Growth and development of *H. armigera* were adversely affected on flowers of all wild species. The larval mortality during first 7 days was higher for the larvae fed on wild relatives than on pigeonpea. Very few larvae survived to the pupal or adult stages, when reared on flowers of wild species as compared to cultivated pigeonpea. Growth index and fecundity were also adversely affected in the larvae reared on wild species and their F_1. The adults emerging from larvae reared on wild species were smaller than the adults which emerged from cultivated pigeonpea.

Sison and Shanower (1994) studied the stability of different plant parts on growth and survival of *H. armigera*. Larvae were reared on flowers, pods and leaves of six short-duration pigeonpea genotypes (ICPL 86005, ICPL 86015, ICPL 86012, ICPL 87101 ICPL 88023 and ICPL 87) under laboratory conditions. Larval and pupal weights were significantly higher, larval developmental period significantly shorter, and adult life span significantly longer when reared on pods compared with flowers and leaves. Larvae reared on ICPL 87 had the shortest larval developmental time, the highest larval and pupal weights, and the longest adult life

span. Lowest larval weights were recorded in ICPL 86012 and ICPL 86015. There was a significant variation in growth, development, and survival of *H. armigera* due to differences in biochemical constituents (nutrients or secondary metabolites) between genotypes and plant parts.

Srivastava and Srivastava (1990) studied antibiosis in chickpea genotypes to *H. armigera* (ICCX 730041, ICC 10613, ICC 10817, ICCL 79048, C 235, K 850, ICC 1403, ICC 3137). The percentage larval survival was lowest (76.8%) on ICCL – 79048, with longest larval period of 24 days and thus exhibited high level of antibiosis.

2.2.3 Morphological and physical resistance

Trichomes are a potentially important resistant mechanism, and have been utilized in developing resistant cultivars of several other crops. Previous work has indicated that for many herbivorous insects such as leafhoppers and Lepidoptera, glandular trichomes provide a resistance mechanism owing to both the compounds exuded by them (Ranger and Hower, 2001; Frelichowski and Juvik, 2001) and their density (Valverde *et al.*, 2001; Gurr and McGrath, 2001).

Non-glandular trichomes and yellow glandular sacs are present on pods and leaves of all *Cajanus* species. Glandular trichomes that release chemicals are confined to the pods of *C. cajan* and *C. platycarpus* and are absent on the pods of *C. scarabaeoides C. platycarpus* pods have the longest non glandular trichomes. Pods of *C. scarabaeoides* are highly pubescent, followed by those of *C. cajan* and *C. platycarpus*. *H. armigera* avoids the highly pubescent *C. scarabaeoides* for oviposition. Trichome density exhibited a negative impact on larval survival, growth

and development. Behavioural study indicated that the neonate larvae were unable to reach the feeding site in time, which led to larval desiccation (John peter, 1995). Differences in physical and biochemical characters between pigeonpea and its wild relatives may account for the relative differences in food preference by the larvae of *H. armigera*. Five types of trichomes have been identified on pods of *Cajanus spp.* three glandular and two nonglandular. Pods of *C. scarabaeoides* have a dense covering of short non-glandular trichomes and lack the long, tubular glandular trichome common on pigeonpea and *C. platycarpus* pods. Pigeonpea and *C. platycarpus* pods are much less densely covered with non glandular trichomes than *C.scarabacoides*. The very dense non-glandular trichomes on pods of *C. scarabaeoides* provide a physical barrier to young *H. armigera* larvae, while the glandular trichomes secrete chemicals that act as attractants to adult moths (Hartlieb and Rembold, 1996), and also act as phagostimulants / antifeedants to the larvae of *H. amigera* (Sharma *et al.*, 2001).

The dense covering of trichomes on pods of *C. Scarabaeoides* was respsonsible for low neonate survival compared with *C. cajan* or *C. platycarpus*. The non glandular trichomes acted as physical resistance mechanism and prevented small larvae from reaching the pod surface to feed. But these trichomes were less effective for larger larvae which were able to establish and feed, but grew more slowly and took longer to develop than the larvae on the other two *Cajanus spp.* The density of non glandular trichomes on *C. scarabaeoides* may also have reduced larval growth and increased larval development period, resulting in lower pupal weight and low fecundity of *H. armigera* on this species (Shanower *et al.*, 1997).

2.2.4 Biochemical mechanisms of resistance

Nutritionally important constituents of a host plant play a significant role in the feeding behaviour of phytophagous insects (Thorstkeinson, 1960). At physiological concentrations, sugar, amino acids, lipids, salts and some secondary plant substances act as phagostimulants. A combination of these components quite often produces synergistic effects (Beck and Hanec, 1958; Thorsteinson and Nayar, 1963; Gothilfs and Beck, 1967; Doss *et al.*, 1982; Doss, 1983).

In addition to being phagostimulants, sterols are important for insect growth and development. Insects are incapable of *de novo* synthesis of the steroid skeleton, which they require to synthesize the moulting harmone, ecdysone. To meet the sterol requirements, the phytophagous insects depend on their host plant or symbionts (Sharma, 1993). Ethyl acetate fraction showed phagostimulant properties compared to sucrose. Sterols (5 mg/disc) and soybean leaf extract (40 mg/disc) in combination with (400 mg/disc) showed synergistic effect as phygostimulants.

Annadurai *et al.*, (1990) suggested that the relative concentrations of various phenols play an important role in determining the suitability of pigeonpea plant tissues for the presence of phloroglucinol in pods which stimulates the growth and enhances the survival of larvae. The compound resorcinol may be the cause of poor larval growth and survival on leaves.

The pods of 12 varieties of pigeonpea belonging to three maturity groups (early, medium, and late) were analyzed at green pod stage and at maturity for various biochemical parameters (proteins, total sugars, phosphorus and potassium). Total sugars on the pods varied at the two stages of pod development,

and indicated that the early maturing varieties (UPAS 120, ICPL 87 and TAT 10) which were susceptible to pod borer damage, had significantly higher total sugar content (3.56 to 4.70%) than the late maturing cultivars viz., PT 35, PT 25, C 11, N 290-21 (2.99 to 3.30% sugar content). Total sugar content showed a significant and positive correlation coefficient with pod borer damage (Knap *et al.*, 1966; Singh and Jotwani, 1980, Khurana and Verma, 1983). Resistant varieties of pigeonpea have lower phosphorus and potassium contents than susceptible ones The polyphenols have been reported by several workers in different crops (Hahn *et al.*, 1981; Khurana and Verma, 1983; Mohan *et al.*, 1987).

Poly phenoloxidase activity in the pods of 12 cultivars of pigeonpea at two stages of growth indicated that the late-maturing cultivars (resistant to pod borer damage) had comparatively much higher activity, followed by medium-maturity cultivars (Murkute *et al.*, 1993). Surface chemicals from pods of pigeonpea and two wild *Cajanus* species also effect the behaviour of *H. armigera* larvae. A filter paper feeding test showed that acetone extract from the surface of pigeonpea and *C. platycarpus* pods contains *H. armigera* feeding stimulants (Shanower *et al.*, 1997) but not in extracts from pods of *C. scarabaeoides.* Feeding stimulants are contained in the trichome exudates. Polar chemicals on the plant surface also stimulate oviposition behaviour of *H. armigera* (Romeis *et al.*, 1999a).

The effect on the larval development of *H. armigera* of caffeoylquinic acids was evaluated by Kimmins *et al.*, (1995). A mixture of compounds containing 5-caffeoylquinic acid (5CQA), 3-caffeoylquinic acid (3CQA) and a novel compound, 1-caffeoyl-4 deoxyquinic acid (1cdQA), which were

extracted from the wild groundnut species *Arachis paraguariensis*, showed inhibitory effects of larval development of *H. armigera*.

A methanol extract from the pod surface of *C. cajan* a feeding stimulant for fifth instar *H. armigera* has shown to contain four main phenolic compounds. The four compounds were identified as isoquercetin, quercetin, quercetin –3-methylether and stilbene. *C. cajan* cultivars that varied in their susceptibility to *H. armigera* were surveyed for the presence of the four phenolic compounds. An absence of quercetn and higher concentrations of iso-quercetene than the cultivated variety characterised pod surface extracts of pod borer resistant cultivars. In addition, the ratio of stilbene to quercetene 3 methyl ether was greater in the pod borer resistant cultivars (Green *et al.*, 2003).

2.3 TOLERANCE

Tolerance provides the plant an ability to produce satisfactory yield in the presence of a pest population that would result in a significant damage in the susceptible plants. Tolerant cultivars do not suppress pest populations, and thus do not exert a selection pressure on the pest population. Effects of tolerance are cumulative as a result of interacting plant growth responses such as plant vigor, inter and intra plant growth compensation, mechanical strength of tissues and organs, and nutrient and growth regulation and partitions. Plants with tolerance mechanisms of resistance have a great value in pest management as such plants prevent the evolution of new insect biotypes, and also help in maintaining the populations of the natural enemies. Development of new insect biotypes capable of feeding on resistant cultivars with antixenotic or antibiosis mechanisms of resistance can be

delayed or minimized by utilizing tolerance as a polygenic resistance (Tingey, 1981).

Patnaik *et al.* (1989) screened eleven pigeonpea genotypes (ICPL Nos. 94, 154, 151, 289, 184, 146, 8317, 8322, 315, 267, and 148) for resistance to *H. armigera,* which were of early-maturity group and determinate type of growth habit. The mean pod damage over three years indicated that ICPL 154 and ICPL 94 recorded low levels of pod damage of 9.8 and 10.9%, respectively, as compared to the other test cultivars.

The relative susceptibility of 40 entries of pigeonpea to attack by larvae of *H .amigera* was determined in field plot tests in Rahuri in1978. None of the entries were free from infestation, but those least susceptible were nos.148 Hy-2, 4725, Phule T-1, AS-71-37, Phule T3, BDN – 2, N-84, BDN-1, N-290-21 and PL-8796. In general, medium late entries were significantly less damaged than late or early entries (Bhosale and Nawale, 1983).

Chapter III

MATERIALS AND METHODS

CHAPTER – III

MATERIALS AND METHODS

Studies on the "Mechanisms of resistance to *Helicoverpa armigera* (Hubner.) in pigeonpea [*Cajanus cajan* (L.) Millsp.]" were conducted at the International Crops Research Institute for Semi Arid Tropics, Patancheru, between June 2000 to December 2002. The materials and methods used in conducting these experiments are elucidated below.

3.1 STABILITY OF RESISTANCE TO *H. armigera* IN PIGEONPEA

The present investigation was conducted at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Patancheru, India. The latitude and longitude are 17° 27'N and 78° 28'E, respectively, and altitude is 545 m above sea level. Four plantings were taken up in two years between 2000-2002.

3.1.1 Experimental material

The material used for the study of 12 pigeonpea genotypes (Table 1) earlier developed at ICRISAT are given below.

Short duration genotypes: ICPL 87, ICPL 98001, ICPL 98008, ICPL 87091, ICPL 88039, T 21, ICPL 187-1, ICP 7203-1. Among these ICPL 87 and ICPL 98001 are determinate types while the other genotypes have a indeterminate type of growth habit. Plant growth habit has a substantial influences on the extent of pod borer attack which plays very important role in pod borer damage.

Table 1: Pigeonpea germplasm characterisation

Genotype	Growth habit	Duration	Plant height (cm)	Stem color	Flower color	Flowering pattern	Pod color	Pod hairiness	Leaf hairiness	Pod length (cm)
ICPL 187-1	Semi-determinate	SD	136	Green	Yellow	Indeterminate	Mixed green and purple	Pubescent	Glabrous	6.3
ICP 7203-I	Semi-determinate	SD	140	Green	Yellow	Indeterminate	Green	Pubescent	Glabrous	6.2
ICPL 88039	Semi-determinate	SD	110	Green	Yellow	Indeterminate	Mixed green and purple	Pubescent	Glabrous	6.5
ICPL 98001	Determinate	SD	90	Green	Yellow	Determinate	Mixed green and purple	Pubescent	Glabrous	6.6
ICPL 98008	Semi-determinate	SD	170	Green	Yellow	Indeterminate	Mixed green and purple	Pubescent	Glabrous	7.0
ICPL 87091	Determinate	SD	66	Green	Red & Yellow	Indeterminate	Mixed green and purple	Pubescent	Glabrous	9.5
T 21	Semi-determinate	SD	140	Purple green	Yellow	Determinate	Mixed green and purple	Pubescent	Glabrous	6.2
ICPL 84060	Semi-determinate	MD	160	Green	Yellow	Indeterminate	Mixed green and purple	Pubescent	Glabrous	6.3
ICPL 87119	Semi-determinate	LD	159	Green	Yellow	Indeterminate	Mixed green and purple	Pubescent	Glabrous	6 2
ICP 7035	Semi-determinate	LD	142	Purple green	Red	Indeterminate	Purple	Pubescent	Glabrous	7.5
ICPL 87	Determinate	SD	78	Green	Yellow	Determinate	Mixed green and purple	Pubescent	Glabrous	7.0
ICPL 332	Non-determinate	MD	176	Green	Yellow	Indeterminate	Mixed green and purple green	Pubescent	Glabrous	6.5

SD = Short duration, MD = Medium duration, LD = Long duration.

Medium duration genotypes: ICPL 84060 and ICPL 332 are medium duration with indeterminate growth habit.

Long duration genotypes: ICP 7035 and ICPL 87119 are of long duration with indeterminate growth habit.

3.1.2 Experimental design

The trials were planted in black precision fields of ICRISAT farm. There were 36 plots (each plot having 4 rows, 4 m long during *kharif* 2000-01 and 6 rows, 4 m long during *kharif* 2002). There were three replications in a randomized complete block design. To reduce the incidence of seed born diseases, the seeds were treated with thiram (3g kg^{-1}) of seed. The treated seed were sown on 22nd June and 21st July 2000. During *kharif* 2001-02 the crop was sown on 26th June and 28th July 2001. The rows were spaced at 75 cms, and the spacing between the plants within a row was 30 cm. The plots were separated by an alley of 1 m. The seeds were sown with a 4-cone planter at a depth of 5 cm below the soil surface at optimum soil moisture conditions. The crop was thinned to a spacing of 30 cm at one month after seedling emergence. Basal fertilizer N:P:K::100:60:40 was applied in rows before sowing. Top dressing with urea @ 80 kg ha^{-1} was given at one month after crop emergence. Interculture of weeding was carried out as and when needed. Insecticide was applied to the untreated plot during the reproductive stage of the crop.

3.1.3 Observations

For this purpose, a 40-cm portion of inflorescence was marked at the pre flowering stage with a ribbon. Five inflorescences were tagged in each plot.

3.1.3.1 Egg and larval counts

Data on number of eggs and larvae were recorded at 5, 7, 9, 20 and 30 days after tagging and presented as total number of eggs and larvae.

3.1.3.2 Days to 50% flowering

Number of days from planting to 50% flowering was recorded as days to 50% flowering.

3.1.3.3 Days to maturity

Number of days from planting to 75 per cent maturity of the plot was recorded as days to maturity.

3.1.3.4 Insect damage score

At harvest the crop was scored for *H. armigera* damage on a 1-9 scale.

1 = <10% pods damaged

2 = 11 to 20%

3 = 21 to 30%

4 = 30 to 40%

5 = 40 to 50%

6 = 50 to 60%

7 = 60 to 70%

8 = 70-80%

9 = > 80% of the pods damaged by *Helicoverpa*.

3.1.3.5 Plant stand at harvest

The total number of plants present in middle 4 rows of each plot were counted at the time of harvest.

3.1.3.6 Per cent pod damage

The number of pods and the pods damaged by pod borer were recorded at maturity in pods harvested from the tagged inflorescences from random three plants. Pod borer damage to pods was quantified by expressing the number of pod borer damaged pods as a percentage of total number of pods.

3.1.3.7 100-seed weight and seed per pod

100-seeds were taken at random from each plant and weighed on a mettler precision balance. Seeds per pod wee taken at random from each plant.

3.1.3.8 Grain yield per three plants

Three plants were selected at random and the grain weight of these plants was expressed as grain yield per three plants.

3.1.3.9 Grain yield per plot and per hectare

Total grain weight for the plot was calculated as plot yield. Then plot yield was computed for hectare yield.

3.1.4 Genotype stability for resistance to *H. armigera*

Data were subjected to analysis of variance using GENSTAT 5.0 release. The significance of differences between the genotypes was determined by

F-test, while the treatment means were separated by least significant difference (LSD) at $P \leq 0.05$. For the twelve pigeonpea genotypes, stability analysis was done for 4 seasons by the method of Eberhart and Russel (1966) and stability statistics were analysed.

3.2 MECHANISMS OF RESISTANCE TO *H. armigera* IN PIGEONPEA

3.2.1 Insect culture

The culture of *H. armigera* was obtained from the laboratory culture maintained at ICRISAT-Patancheru, India. The lab culture was regularly supplemented with field collected larvae. The larvae were reared on the chickpea based diet (Armes *et al.*, 1992) at 27°C (Table 2). The adults were released in a cage with nappy liners for oviposition. The adults were supplied with 10% sucrose on absorbant cotton inside the cage. Eggs laid on the liners were sterilized with 1% sodium hypochloride, and transferred into the cups for rearing on the artificial diet. Antixenosis and antibiosis components of resistance to the pod borer, *H. armigera* were studied for the 12 genotypes under laboratory conditions. Among them; ICPL 87 and ICPL 332 were used as susceptible and resistant checks, respectively.

3.2.2 Antixenosis for oviposition

Nonpreference for oviposition was studied under no-choice, dual-choice and multi- choice conditions (25 - 27°C and 65 – 90% RH and a photoperiod 12 hours). The twigs /inflorescences used for studying antixenosis were procured from the field. The plant material was thoroughly examined for the presence of eggs or larvae before use in laboratory.

Table 2: Chemical composition of diet used for rearing *H. armigera* larvae (Armes *et al.*, 1992)

S. No.	Ingredients	Quantity
1	Chickpea flour	300.00 g
2	Ascorbic acid	4.70 g
3	Methyl-p- hydroxybenzoate	5.00 g
4	Sorbic acid	3.00 g
5	Auromycin powder	11.50 g
6	Vitamin stock solution	10.00 ml
7	Water	450.00 ml
8	Yeast	48.00 g
9	Agar	17.30 g
10	Water (for yeast/agar)	800.00 ml
	Vitamin stock solution	
1	Nicotinic acid	1.528 g
2	Calcium pantothenate	1.528 g
3	Riboflavine	0.764 g
4	Aneurine hydrochloride	0.382 g
5	Pyridoxine hydrochloride	0.382 g
6	Folic acid	0.382 g
7	D-Biotin	0.305 g
8	Cyanocobal amine	0.003 g
9	Water	500 ml

3.2.2.1 Oviposition nonpreference under no-choice conditions

One genotype was tested in a wooden cage (30 x 30 x 30 cm). Five inflorescences (30 cm long) with few leaves were brought from the field and placed in a conical flask filled with water. Five pairs of 2-day old moths were released inside the cage. Moths are provided with sucrose solution in a cotton swab through out the experiment. After releasing the moths in the cages, the moths were allowed to oviposit for three nights on the test plants. To avoid predation by the ants, tangle foot ® glue was smeared on all the four legs of the cages. Observations were recorded on the number of eggs laid on each inflorescence placed in a cage. The moths were allowed to oviposit on the test entries for three consecutive nights. Each experiment was replicated five times. Data were subjected to analysis of variance using completely randomized design (Plate 1).

3.2.2.2 Oviposition preference under dual-choice conditions

Non- preference for oviposition under dual-choice conditions was studied by keeping a test variety with a susceptible check, ICPL 87 inside the wooden cage as described above. The inflorescence (30 cm long) were obtained from the field. Five inflorescences each of the test variety and the susceptible check were kept in two conical flasks separately at the corner inside the cage. Five pairs of two day old moths were released inside the cage. The moths were provided with sucrose solution in a cotton swab. To avoid predation by the ants, tangle foot ® glue was applied to all the four legs of the wooden cage. The experiment was replicated five times. Significance of difference between the two test genotypes was compared by paired T-test at P=0.05. There were five replications for each entry (Plate 2).

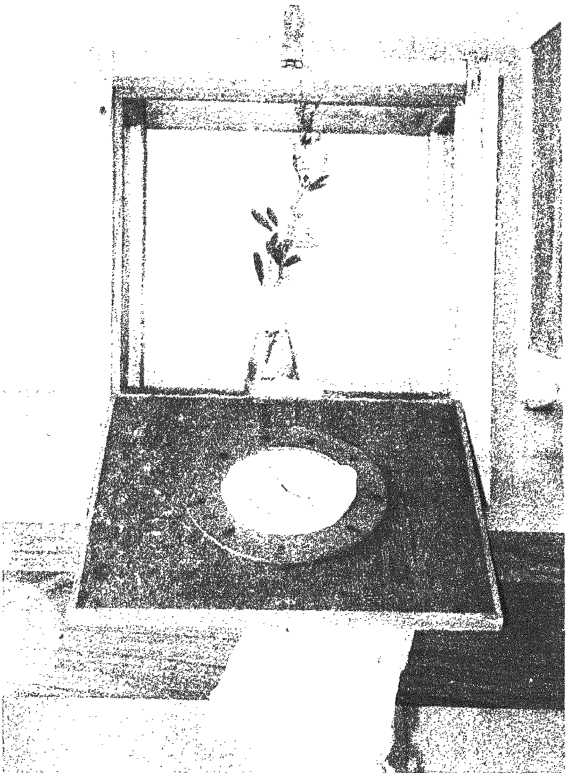


Plate 1: Cage used for studying relative oviposition preference of ***H.armigera*** moths on pigeonpea genotypes in laboratory (2001-2002).

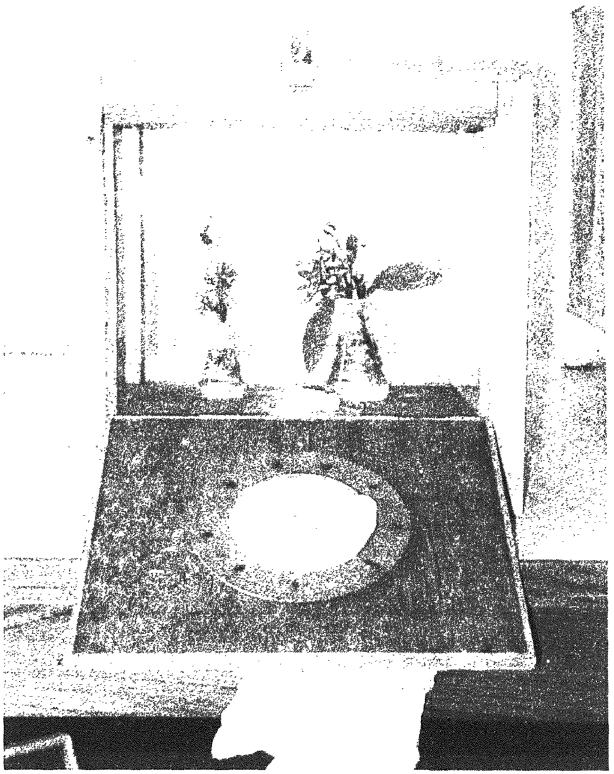


Plate 2: Relative oviposition preference of ***H.armigera*** moths on pigeonpea genotypes under dual-choice conditions in laboratory (2001-2002).

Relative ovipositional preference =

$$\frac{\text{No of eggs laid on test variety x No of eggs laid on standard variety}}{\text{No of eggs laid on Test variety + No of eggs laid on standard variety}} \times 100$$

3.2.2.3 Oviposition non-preference under multi-choice conditions

Non-preference for oviposition under multi-choice conditions was studied by keeping all the 12 genotypes inside a wooden cage (80 x 70 x 60 cm) placed inside a growth chamber The growth chamber was maintained at 26° C during the day and 20°C during night Relative humidity was 70%, and photoperiod – 12 hours Inflorescences of the test genotypes were brought from the field and kept in a conical flask filled with water Conical flasks (containing the inflorescences) of all the test genotypes were arranged inside the wooden cage in completely randomized block design Thirty pairs of two day old adults were released inside the cage Moths were provided with sucrose solution in a cotton swab The moths were allowed to oviposit on the test entries for three consecutive nights To avoid predation by the ants, tangle foot ^{R} glue was applied to all the four legs of the wooden table (Plate 3) Observations were recorded on the number of eggs laid on each genotype The experiment was replicated thrice Data were subjected to analysis of variance

3.2.3 Antibiosis mechanism of resistance to *H. armigera*

3.2.3.1 Growth and survival of *H. armigera* on leaves of different pigeonpea genotypes

Neonate *H. armigera* larvae were fed on the tender leaves of the 12 pigeonpea genotypes The leaf material obtained from the field was placed in a 250 ml plastic cups Ten neonate larvae were released on the leaves with the help of

Plate 3: Relative oviposition preference of ***H.armigera*** moths towards 12 pigeonpea genotypes under multi-choice cage conditions in laboratory (2001-2002).

a fine camel hair brush. A moistened filter paper was attached to the inner side of the lid and the plastic cups were covered immediately. The plastic cups were kept in the lab at 27+2°C and 45 to 65%RH. The leaves were changed every alternate days. From fifth day onwards, the larvae were reared individually in cups to avoid cannibalism. Larval weights and mortality were recorded on 5, 10 and 15 days after release. Data on larval and pupal period, adult emergence, and pupal weights were also recorded. The experiment was conducted in completely randomized design. There were 5 replications. Data was subjected to ANOVA.

3.2.3.2 Growth and survival of *H. armigera* on flowers and pods of different pigeonpea genotypes

Under natural conditions, the larvae first feed on flowers, and then on pods. Therefore, neonate *H. armigera* larvae were fed on the flowers for 5 days, and then transferred to pods of respective pigeonpea genotypes. The flowers and pods were kept in petri plates with a moistened filter paper attached to the lid. The petri plates were kept in the laboratory at 27+2°C and 45 –65% RH. Larval weights were recorded on 5, 10, and 15 days after release. Data was also recorded on larval and pupal period, pupal weights, and adult emergence. The experiment was conducted in a completely randomized design with five replications, and 10 larvae were released on each replication. Data was subjected to ANOVA. Data on larval weight, larval mortality on 10^{th} day after initiation, larval and pupal period, pupal weight and adult emergence of the above two experiments were subjected to principle component analysis.

3.2.3.3 Standardisation of artificial diet impregnated with lyophilized leaf powders of pigeonpea

Antibiosis component of resistance was also measured by impregnating lyophilized plant material into the artificial diet. Leaves of 12 genotypes were collected from two month old plants raised under field conditions. Leaves were removed from the plant at the growing point, and freeze dried in a lyophilizer for 36 h to avoid changes in chemical composition of the leaves, and then powdered in a Willey Mill to < 80 mesh size.

For studying the effect of different amounts of leaf powder in the artificial diet on survival and development of *H. armigera*: For this purpose 0, 5, 10, 15, and 20 g of pigeonpea leaf powder ICPL 87 (susceptible check) and ICPL 332 (resistant check) was added in 250 ml- artificial diet. Pigeonpea leaf powder was soaked in 100 ml of warm water (70°C) and blended with fraction-A (Table 3 and Plate 4) for two minutes. Agar was boiled in 80 ml of water (Fraction-B), cooled to 40°C, and then poured into the blender containing Fraction –A. Formaldehyde was added, finally and all the constituents blended for three minutes. Each treatment was replicated three times (a small cup of 50 ml capacity containing 20 ml diet). One first instar larva was released in each cup.

Observations on larval mortality and larval weights were recorded on 10^{th} day. Observations were also recorded on pupal weights, per cent pupation, per cent adult emergence, and larval and pupal periods. Data was subjected to ANOVA.

Table 3: Composition of artificial diet impregnated with lyophilized leaf powder

Fraction-A	Quantity
Chickpea flour	75.00 g
Ascorbic acid	1.18 g
Methyl-p-hydroxybenzoate	1.25 g
Sorbic acid	0.75 g
Aureomycin powder	2.88 g
Vitamin stock solution	2.50 ml
Water	112.50 ml
Yeast	12.00 g
Fraction B	
Agar	4.36 g
Water (for yeast/agar)	200.00 ml
Leaf powder	20.00 g

3.2.3.4 Standardisation of artificial diet impregnated with lyophilized pod powders of pigeonpea

For studying the effect of different amounts of pod powder in the artificial diet on survival and development of *H. armigera*: For this purpose 0, 5, 10, 15, and 20 g of pigeonpea pod powder ICPL 87 (susceptible check) and ICPL 332 (resistant check) was added in 250 ml- artificial diet. Pigeonpea pod powder was soaked in 100 ml of warm water (70°C) and blended with fraction-A (Table 3) for two minutes. Agar was boiled in 80 ml of water (Fraction-B), cooled to 40° C, and then poured into the blender containing Fraction –A. Formaldehyde was added, finally and all the constituents blended for three minutes. Each treatment was replicated three times (a small cup of 50 ml capacity containing 20 ml diet). One first instar larva was released in each cup.

Observations on larval mortality and larval weights were recorded on 10^{th} day. Observations were also recorded on pupal weights, per cent pupation, per cent adult emergence, and larval and pupal periods. Data was subjected to ANOVA.

3.2.3.5 Growth and survival of *H. armigera* on lyophilized leaf powder

Leaf powder from 12 genotypes was impregnated in artificial diet. For each genotype two treatments with different proportions of chickpea flour and pigeonpea leaf powder (65:10 :: chickpea flour : pigeonpea leaf powder) were tested. The preparation of diet was same as above. Each treatment was replicated 3 times. One first instar larva was released in each cup and the cups were placed in the rearing room In the rearing room, temperature was maintained at 28 ± 1°C, 60 – 70% RH and photoperiod of 12 h.

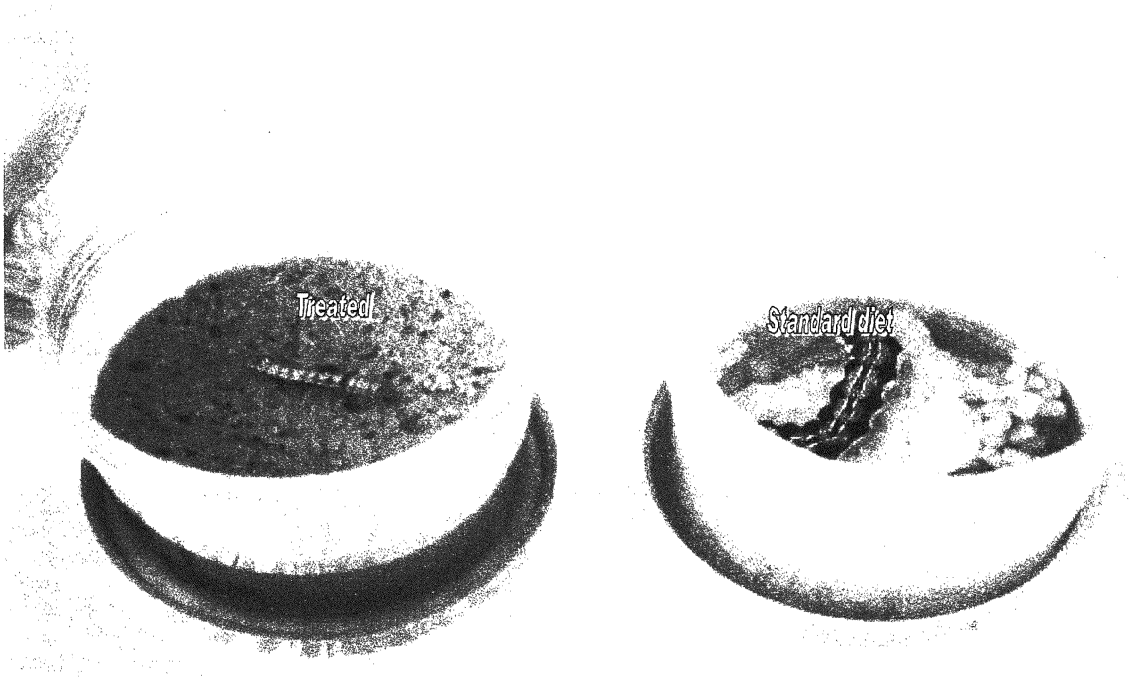


Plate 4: Growth and development of ***H. armigera*** in artificial diet impregnated with lyophilized pigeonpea leaf power (2000-02).

Data on larval mortality and larval weight on 10th day, pupal weights, per cent pupation, per cent adult emergence, and larval period and pupal periods were recorded.

The data were subjected to analysis of variance.

3.2.3.6 Growth and survival of *H. armigera* on lyophilized pod powder

Pod powder from 12 genotypes was impregnated in artificial diet. For each genotype two treatments with different proportions of chickpea flour and pigeonpea pod powder (65:10 :: chickpea flour : pigeon pea pod powder) were tested. The preparation of diet was same as above. Each treatment was replicated 3 times. One first instar larva was released in each cup and the cups were placed in the rearing room. In the rearing room, temperature was maintained at 28 ± 1°C, 60 – 70% RH and photoperiod of 12 h.

Data on larval mortality and larval weight on 10th day, pupal weights, per cent pupation, per cent adult emergence, and larval period and pupal periods were recorded. The data were subjected to analysis of variance. Data on larval weight, larval mortality on 10th day after initiation, larval and pupal period, pupal weight and adult emergence of the above two experiments were subjected to principle component analysis.

3.2.3.7 Larval feeding on inflorescences of 12 pigeonpea genotypes

Terminal inflorescences of 12 pigeonpea genotypes were cut with scissor and immediately placed in a 250 ml cup with 3% agar agar. Ten neonate larvae were released with the help of a fine camel hair brush. Observations on larval

weights and larval mortality were recorded after five days. The experiment was conducted in a completely randomized design with 12 treatments and 5 replications. Data was subjected to ANOVA (Plate 5).

3.2.4 Trichome types and their density in 12 pigeonpea genotypes

Trichomes are the most common morphological structures which play an important role in insect host plant interaction in pigeonpea and the variation in their forms and functions quite often are associated with plant resistance to insect attack (Southwood, 1986). Hence the study was carried out to identify different types of trichomes and their density in 12 different pigeonpea genotypes.

The presence of trichomes on pods and calyx was recorded by collecting a minimum of 15 pods and flowers from each accession and there were three replications. The material was preserved in a fixation (Acetic acid, absolute alcohol 1:3) and examined under a Zeiss stereomicroscope (Carl Zeiss Inc., Thom Nood, NY) at a magnification of 32X with an ocular measuring grid density of trichomes was recorded based on mean of 15 pods.

3.2.5 Biochemical analysis

3.2.5.1 Estimation of nitrogen, phosphorus, potassium and protein content

Estimation of nitrogen, phosphorus and potassium contents was done by collecting flowers in the field during flowering stage of the crop. The flowers were subjected to lyophilisition and powdered. The flower powder was then used for analysis. Similar procedure was followed for pods also. Nitrogen was estimated by microkjeldahls method (Jackson, 1967), phosphorus by Ammonium meta

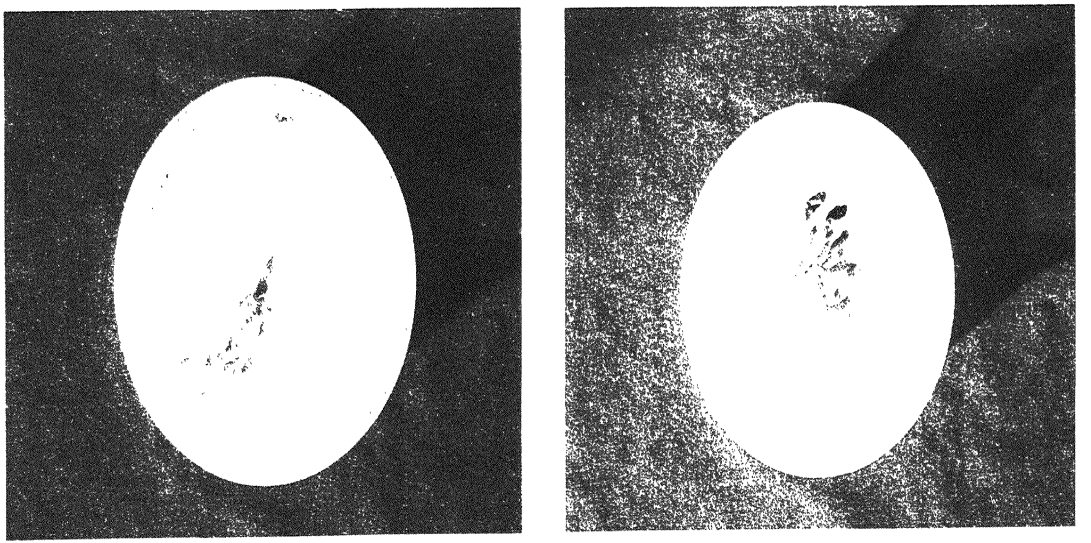


Plate 5 Relative susceptibility of ***H.armigera*** neonate larvae towards inflorescences of pigeonpea genotypes inserted in agar-agar under laboratory conditions (2001-2002)

venadata yellow colour method (Jackson, 1967) and potassium by flame photometer method (Jackson, 1967). Estimation of proteins was calculated by multiplying the nitrogen content with factor 6.24.

3.2.5.2 Estimation of reducing sugars

For estimating the total soluble sugars present in leaves and pods of pigeonpea, the material was extracted with hot aqueous-ethyl alcohol. On treatment with phenol sulphuric acid, the sugars produced a stable and sensitive golden yellow color. The absorbance of the golden yellow color was measured at 490 nm, which was used to estimate percentage of total soluble sugars present in leaves and pods.

The leaves and pods of the test varieties were collected from the crop raised in the field, and were oven dried for 12 h. The oven-dried material was then powdered in a Willey mill, and defatted by using hexane. Ethyl alcohol (80%), 5% phenol (5 g phenol dissolved in water and volume made up to 100 ml), 96% sulphuric acid (specific gravity 1.84), glucose (w/v) standard (stock solution: 1000 mg/1000 ml), and glucose working standard (12.5 ml of stock standard pipetted into a 100 ml volumetric flask, and volume made up to 100 ml, to have the final concentration of 125 μg/ml) were used for estimating the total soluble sugars.

From the defatted material, 100 mg sample was weighed out into a boiling test tube, to which 25 ml of hot 80% ethanol was added. The mixture was vigorously shaken on a vortex mixer. The material was allowed to settle for 30 minutes and the supernatant was filtered by passing through a Whatman No. 41 filter paper. This step was repeated thrice for complete extraction of sugars. By placing the extract on hot sand bath, ethanol was evaporated completely. After complete

removal of ethanol, 3 ml water was added to dissolve the contents. One ml aliquot from the above solution was pipetted into a test tube, and 1 ml of 5% phenol and 5 ml of 96% sulphuric acid were added. The mixture was shaken vigorously on a vortex mixer. The tubes were allowed to cool in cold water. A blank was prepared by taking 1 ml water. Absorbance of the golden yellow color was red at 490 nm using Spectronic 21.

Standards with different concentrations (i.e., 25, 50, 75, 100, and 125µg of glucose) were prepared from the working standard, and their absorbance was read by taking 1 ml aliquats.

Percent total soluble sugars were calculated by using the formula:

$$\frac{\text{Conc. of Std}}{\text{Absorbance of Std}} \times \text{Abs. of 1 ml extract} \times \frac{1}{1000000} \times \frac{3\text{ml}}{0.1\text{g}} \times 100$$

Data recorded viz., nitrogen, potassium, phosphorus, protein, sugars in pods and per cent pod damage under field conditions was subjected to principle component analysis.

3.2.6 Bioassay of pod surface extracts from ICPL 87 (susceptible check) and ICPL 332 (resistant check) using glass fibre discs

Extracts of the pod surfaces of ICPL 83, ICPL 87 and ICPL 332 were prepared by placing pods of known surface area into 500 ml of hexane or methanol, and stirred for 120 seconds with a glass rod. Each extract was then gravity filtered before being evaporated under vacuum to dryness. Extracts of the pod surfaces of ICPL 87 were re-dissolved in either hexane or methanol so that 100 µl of solution contained a quantity of extract equivalent to 3.46 cm^2 of pod surface (the area of

glass fibre disc). The larvae were presented with a naturally occurring concentration of extract. Aliquots (100 µl) were then pippeted onto each glass fibre disc, and the discs were air dried for 24 h. Subsequently, each disc was weighed and placed into separate plastic petri dish (9 cm diameter) along with a pre-weighed, untreated disc. Both the discs were moistened with 100 µl of distilled water as the larvae does not feed on dry discs. One third instar larva was placed in each Petri dish. The experiment was replicated 20 times. After 24 h the larvae were removed from petri dishes, and the glass fibre discs were dried and re-weighed. All discs were kept in growth chambers maintained at 12 h/27°C (light: 12h/20°C (dark) (Plate 6).

Feeding (FI) and antifeedant activity were calculated using the formula given below:

$$FI = (C-T)/C+T \times 100$$

C = Amount of control disc eaten

T = Amount of treated disc eaten

The antifeedant activity was computed by using the formula given below:

$$\text{Antifeedant activity} = \frac{\text{Unconsumed area of control disc} - \text{Unconsumed area of treated disc}}{\text{Total disc area}} \times 100$$

3.2.7 Bioassay using plant material

The aim of this experiment was to investigate the relative preference of third-instar larvae of *H. armigera* for different genotypes of *C. cajan*. Leaves, flowers, and pods of similar age group and free from insect eggs and larvae were collected from the field and brought to the laboratory. The preference of the larvae of *H. armigera* to the leaves, flowers, and pods of 12 genotypes were studied under no-choice, dual-choice and multi-choice conditions.

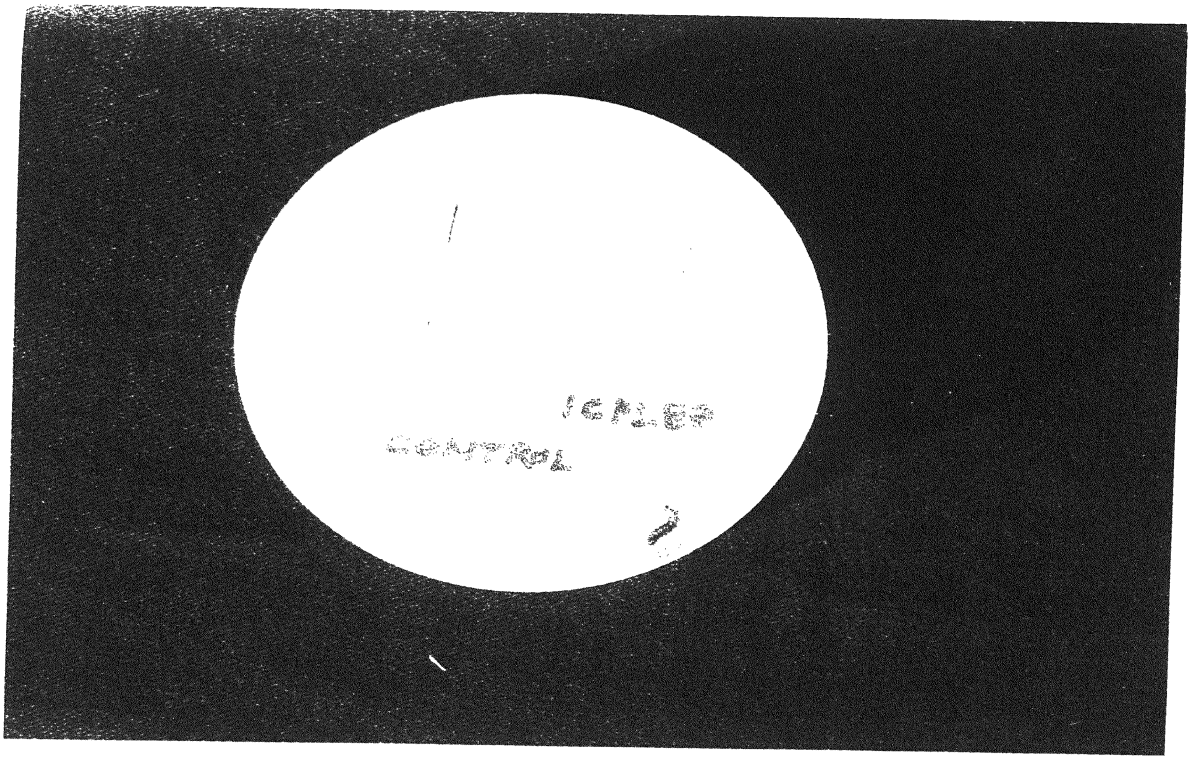


Plate 6 Bioassay of pod surface extracts from *C.capan* using glass fibre discs with 3rd instar larva of *H.armigera* under laboratory conditions (2001-2002)

3.2.7.1 Feeding preference under no-choice conditions

In this assay, a single leaf of a variety was kept in a petri dish arena, and one 3rd instar larva was released in each petri dish. The extent of leaf feeding was rated visually on a 1-9 damage rating scale after 24 and 48 h. This procedure was repeated for all the 12 genotypes. There were 5 replications for each genotype. Similar procedure was followed for leaves and flowers as well.

3.2.7.2 Feeding preference under dual-choice conditions

Under dual-choice conditions, the larva was given a choice between a leaf of a susceptible genotype (ICPL 87) and a leaf of the test genotype in a petri dish arena (9 cm). A single 3rd instar larva was released in each petri dish. The extent of leaf feeding was recorded visually on a 1-9 damage rating scale, after 24 and 48h. The procedure was repeated with all genotypes. Similar procedure was followed for leaves and flowers as well.

3.2.7.3 Feeding preference under multi-choice conditions

Under multi-choice condition the larvae were offered a choice of flowers of 4 genotypes (the 12 genotypes were divided into three sets and tested along with the susceptible check ICPL 87). Flowers from four genotypes were kept in a petri dish arena (9 cm) along with the check (ICPL 87). Ten 3rd instar larvae were released in each petri dish arena. The extent of larval feeding was rated using visually on a 1-9 damage rating scale after 24 and 48 h. The experiment was repeated five times. In the latter stage, the test genotypes were divided into short-duration genotypes and long- duration types. Eight pods from the short-duration varieties were arranged in a petri dish arena, and the experiment was replicated five

times. Ten third-instar larvae were released in each petri dish, and the larval feeding was assessed visually on a 1-9 rating scale after 24 and 48 hr.

3.2.7.4 Effect of extracting the pod surface chemicals by different solvents on feeding preference by the *H. armigera* larvae

To study the effect of the pod surface chemistry on the behaviour of 3rd instar larvae of *H. armigera*, the larvae were presented with the pods of all the 12 genotypes under no- choice and dual-choice conditions.

3.2.7.4.1 Preparation of extracted pods

The pods of all the genotypes are dissolved in 200 ml of ether hexane, methanol or double distilled water and stirred for 120 seconds with a glass rod. The extracted pods were left to air dry for 2 hrs to allow any remaining solvent to evaporate. The 3rd instar larvae were exposed to (a) control pod, and a pod extracted in hexane, (b) control pod and a pod extracted in methanol, (c) control pod and a pod extracted in distilled water.

3.2.7.4.2 No-choice conditions

The 3rd instar larvae of *H. armigera* are released in a petri dish with a single pod. Singe pod may be 1) without treatment (which acts as a check), 2) extracted in hexane, 3) extracted in methane, 4) extracted in distilled water (Plate 7).

The experiment was replicated 20 times with all the twelve genotypes. The damage ratings were observed after 24 hrs and 48 hrs.

Plate 7 Relative preference of pigeonpea pods to ***H.armigera*** under no choice cage conditions in laboratory (2000-2001)

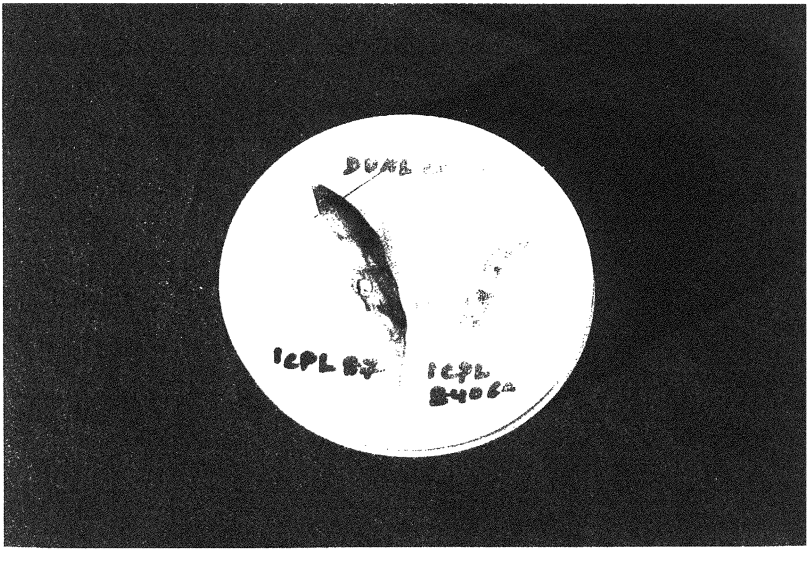


Plate 8 Relative preference of pigeonpea pods to ***H.armigera*** under dual choice cage conditions in laboratory (2000-2001)

3.2.7.4.3 Dual-choice conditions

The effects of pod surface chemistry on the food selection behaviour of larvae were investigated by presenting the larvae with choices between pods that had been surface extracted in either hexane, methanol or water and un extracted pods for all the twelve genotypes (Plate 8).

The damage ratings were observed after 24 h and 48 h. Solvents of different polarity (high polarity – water, intermediate polarity – methanol, apolar – hexane) removed a different compliment of compounds from the pod surfaces. The experiment was replicated 20 times.

3.3 TOLERANCE

Tolerance component of resistance in 12 pigeonpea genotypes was studied by comparing the chemically protected (sprayed) and unprotected crop (unsprayed) plots. The plot size was 45 sqm for each treatment. The crop in the protected plots was sprayed five times during flowering and pod formation stages with different insecticides. Five sprays of 3 insecticides (methomyl, cypermethrin and monocrotophos) with a knapsack sprayer were applied to each plot at 10 to 15 days interval starting at flower initiation. Observations on yield and population of *H. armigera* larvae were made for each treatment (Plates 9 and 10). Counts of the larvae were first made visually at initiation of flowering, and were continued at weekly intervals until harvest on the tagged inflorescences. The number of damaged and total pods were counted on three plants at random from the protected and unprotected plots at harvest. The two treatments in respect of various parameters of grain yield were compared by using the split plot technique. The mean weight of

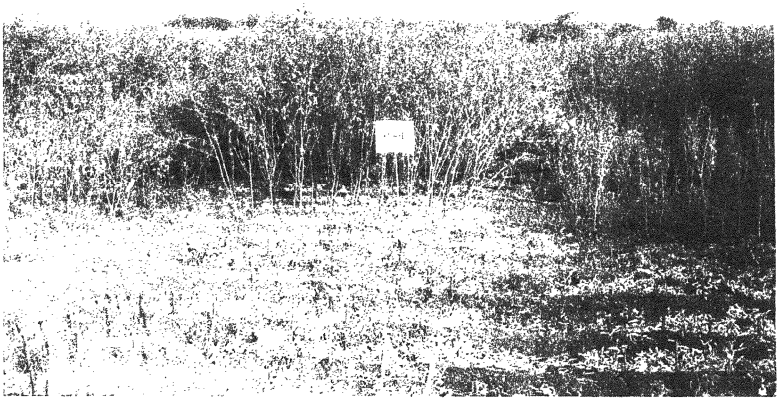


Plate 9: Tolerance to ***H.armigera*** damage in pigeonpea genotypes under protected conditions (2001-2002).

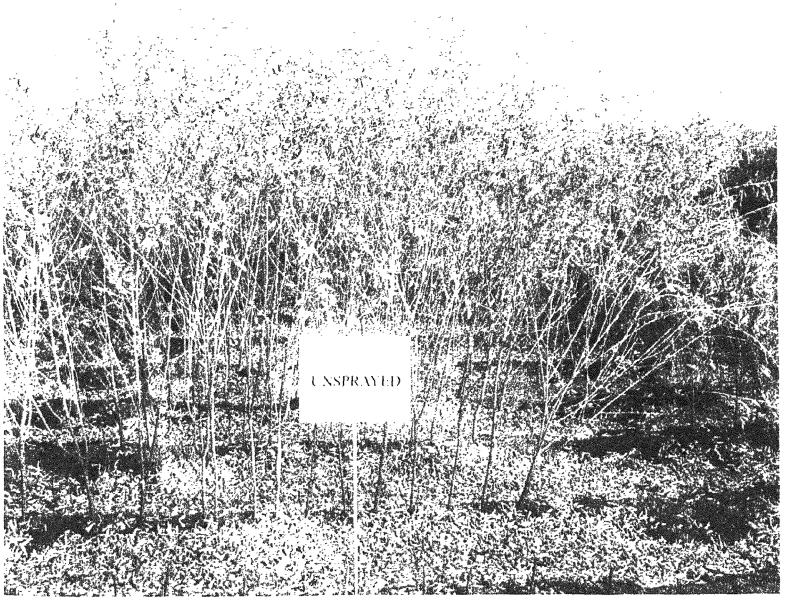


Plate 10: Tolerance to ***H.armigera*** damage in pigeonpea genotypes under unprotected conditions (2001-2002).

total expected grains was calculated on the basis of 100 healthy pods in the protected and unprotected plots. Avoidable loss due to *H. armigera* damage was calculated (Taneja and Nawanze, 1989). The assessment of loss in yield of 12 pigeonpea genotypes by the grain pod borer, *H. armigera* was done using the following formulae.

$$\text{Loss in grain weight} = \frac{\text{Mean weight of total expected grains} - \text{Mean weight of total actual grains}}{\text{Mean weight of total expected grains}}$$

$$\text{Avoidable loss (\%)} = \frac{\text{Average loss in grain weight in Unprotected crop} - \text{Average loss in grain weight in protected crop}}{\text{Average loss in grain weight in unprotected crop}} \times 100$$

$$\text{Yield gain} = \frac{\text{Sprayed yield x Unsprayed yield}}{\text{Unsprayed yield}} \times 100$$

Tolerance was calculated using the following formulae

$$\text{Tolerance} = \frac{\text{Sprayed yield x Unsprayed yield}}{\text{Sprayed yield}} \times 100$$

$$\text{Tolerance index} = \frac{\text{Sprayed yield x Unsprayed yield}}{\text{Sprayed yield}}$$

Data on number of eggs, larvae, damage rating, pod damage per cent and grain yield was subjected to principle component analysis.

Chapter IV

RESULTS

CHAPTER – IV

RESULTS

Studies on the mechanisms of resistance to *Helicoverpa armigera* (Hubner) in pigeonpea [*Cajanus cajan* (L.) Millsp.] were conducted at the International Crops Research Institute for Semi Arid Tropics, Patancheru between June 2000 to December 2002. The results of these experiments are elucidated below.

4.1 STABILITY OF RESISTANCE TO *H. armigera* IN PIGEONPEA

During the 2000 rainy season in the first planting there were significant differences among the genotypes in visual damage rating (DR), 100-seed weight, per cent pod damage, and days to 50% flowering. The differences were not significant among the genotypes tested for days to maturity, seeds per pod, number of eggs and larvae at 5th, 7th, 9th, 20th and 30th days after flowering, and grain yield. During the 2001 rainy season there were significant differences in 100-seed weight, days to 50% flowering, and grain yield. There were no significant differences among genotypes for damage rating, pod damage per cent, seeds per pod, days to maturity, and numbers of eggs and larvae at 5th day, 7th day, 20th and 30th days after flowering.

During the 2001 rainy season in the first planting there were significant differences in days to 50% flowering, visual damage rating, grain yield per plot, 100-seed weight and also for number of eggs and total larvae. There were no significant differences among the genotypes for pod damage per cent, days to

maturity and seeds per pod. In the second planting, there were significant differences in pod damage, damage rating, 100-seed weight, grain yield, and total eggs and larvae. There were no significant differences among genotypes for days to 50% flowering, days to maturity, seeds per pod. Thus there was strong genotype*environment interaction for different parameters recorded.

4.1.1 Eggs and larvae

During the 2000 rainy season, among the short-duration genotypes, lowest number of eggs were recorded in ICPL 187-1(4.27), while lowest number of larvae were recorded on ICPL 98001 (4.04) (Table 4 and Fig.1). In case of long-duration genotypes lowest number of eggs were recorded in ICPL 87119 (4.28) while lowest number of larvae were recorded on ICPL 332 (4.21). In second planting (Table 5 and Fig.2) lowest number of eggs were recorded on ICPL 87119 (4.22) and lowest number of larvae on ICPL 332 (3.33) followed by ICP 7035 (3.67) among long duration genotypes. In case of short duration genotypes lowest number of eggs were recorded on T 21 (4.13) and lowest number of larvae on ICPL 88039 (4.80).

During the 2001 rainy season there were significant differences in total number of eggs and larvae among the genotypes tested. Lowest number of eggs were recorded on ICPL 98008 (2.47), and T21 (3.09) while lowest number of larvae were recorded on ICPL 98001 (1.90), followed by ICPL 98008 (2.84) and T 21 (2.94) (Table 6 and Fig.3). Amongst the long-duration genotypes lowest number of eggs were recorded on ICP 7035 (2.74). In the second planting (Table 7) lowest number of eggs were recorded on ICPL 98008 (2.16) and ICPL 7203-1 (2.34). Lowest number of larvae were recorded on ICPL 98001 (2.54) followed by

Table 4: **Number of *H. armigera* eggs, larvae and pod damage in 12 pigeonpea genotypes in rainy season, first planting (2000-2001)**

Genotype	No. of flowers	Eggs inflorescence^{-1}					Total eggs	Larvae inflorescene^{-1}					Total larvae	* Pod damage rating	Pod borer damage (%)
		5th day	7th day	9th day	20th day	30th day		5th day	7th day	9th day	20th day	30th day			
ICPL 187-1	85.80	0.95	0.79	0.87	0.75	0.91	4.27	0.95	0.75	0.86	0.91	0.91	4.38	4.67	21.75
ICP 7203-1	97.33	1.05	0.84	0.91	0.71	0.95	4.45	1.17	0.75	1.07	0.87	1.02	4.87	4.67	34.45
ICPL 88039	63.73	1.05	0.87	0.79	0.79	0.84	4.34	0.94	0.84	0.79	0.88	0.87	4.27	2.33	44.37
ICPL 98001	71.07	1.05	0.79	0.86	0.71	0.87	4.29	0.83	0.79	0.71	0.79	0.91	4.04	6.67	24.32
ICPL 98008	66.47	1.12	0.79	0.79	0.71	0.87	4.29	0.95	0.75	1.11	0.95	1.05	4.79	3.67	39.43
ICPL 87091	70.00	1.13	1.22	1.11	0.98	1.10	5.54	0.98	0.79	0.98	0.98	1.01	4.75	7.00	22.68
T 21	72.20	1.02	0.84	0.75	0.71	0.98	4.29	0.86	0.84	0.89	0.98	0.94	4.51	6.67	52.29
ICPL 84060	100.90	1.40	0.79	0.71	0.71	0.91	4.52	0.91	0.71	0.79	0.98	0.94	4.33	2.67	37.91
ICPL 87119	47.87	0.98	0.71	0.79	0.75	1.05	4.28	0.91	0.75	0.89	0.91	0.91	4.37	3.00	52.22
ICP 7035	77.00	1.11	1.00	1.11	0.84	1.14	5.21	0.91	0.87	0.75	0.95	0.98	4.46	4.33	40.86
Controls															
ICPL 332 (R)	71.00	1.45	0.75	0.75	0.71	1.12	4.77	0.89	0.71	0.75	0.95	0.91	4.21	5.67	31.09
ICPL 87 (S)	73.00	1.20	1.14	1.08	0.98	0.98	5.37	1.05	0.84	1.08	0.98	0.95	4.89	8.33	46.02
F Prob.	0.001	0.01	<0.001	0.006	<0.001	0.467	<0.001	0.199	0.199	0.29	0.09	0.73	<0.001	<0.01	<0.001
LSD at 5%	19.56	0.24	0.15	0.23	0.30	0.30	0.62	0.21	0.21	0.14	0.13	0.19	1.50	2.50	10.09
CV (%)	15.50	0.14	10.10	15.40	18.40	18.40	12.50	13.30	13.30	10.40	8.40	11.70	17.50	29.70	16.00

R - Resistant check, S - Susceptible check; *Pod damage Rating = 1<10% pods damaged and 9 = >80% pod damaged.

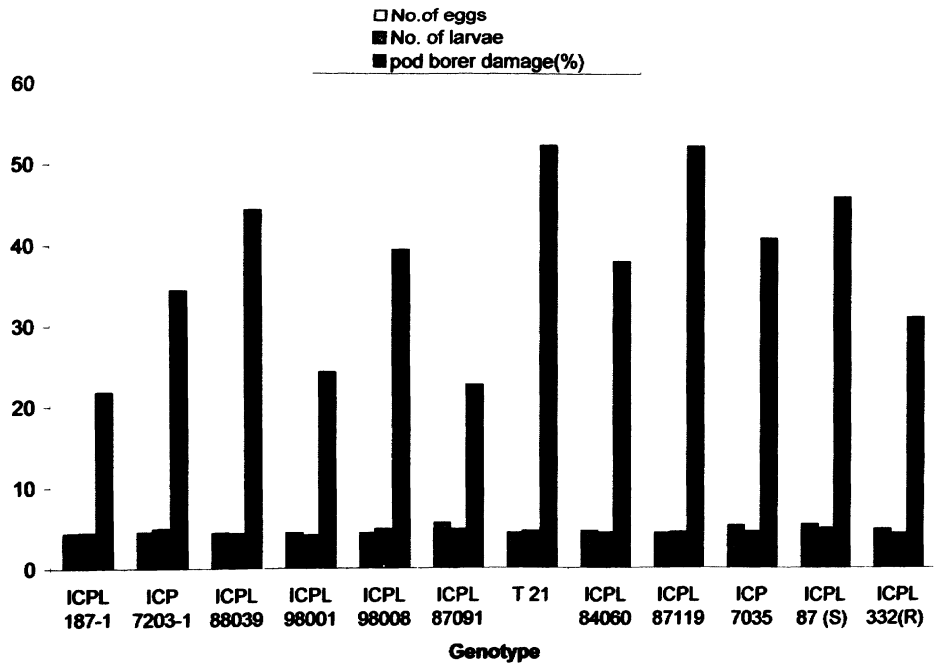


Fig.1 : Number of *H. armigera* eggs, larvae and pod damage in 12 pigeonpea genotypes, first planting (2000-2001)

Table 5: Number of *H. armigera* eggs, larvae and pod damage in 12 pigeonpea genotypes in rainy season, second planting (2000-2001)

Genotype	No. of flowers per plant	Eggs inflorescence^{-1}						Larvae inflorescence^{-1}						Pod damage* rating	Pod borer damage (%)
		5th day	7th day	9th day	20th day	30th day	Total eggs	5th day	7th day	9th day	20th day	30th day	Total larvae		
ICPL 187-1	88.93	0.95	1.01	0.97	0.79	0.71	4.38	0.94	1.12	1.10	0.98	1.05	5.24	8.00	74.18
ICP 7203-1	97.67	0.86	1.16	0.99	0.90	0.71	4.60	0.79	1.18	1.19	1.05	1.16	5.36	6.67	59.08
ICPL 88039	62.87	1.18	0.91	1.08	0.84	0.79	4.76	0.87	1.04	1.05	0.84	1.02	4.80	8.00	47.66
ICPL 98001	70.47	1.11	1.05	1.07	0.95	0.83	4.98	0.98	1.07	1.08	0.98	1.01	5.11	6.00	60.90
ICPL 98008	69.60	1.02	1.01	1.29	0.83	0.71	4.84	1.18	1.19	1.22	1.02	1.11	5.69	8.67	83.85
ICPL 87091	71.40	1.35	1.05	1.17	1.17	1.10	5.82	1.13	1.13	1.29	1.22	1.27	6.02	7.33	51.15
T 21	74.13	0.82	0.95	0.91	0.75	0.71	4.13	0.90	0.90	1.02	1.07	1.07	4.96	6.67	56.11
ICPL 84060	99.60	0.84	0.83	0.83	1.16	0.71	4.35	0.84	0.83	0.93	0.95	0.98	5.92	5.00	69.03
ICPL 87119	44.33	0.95	0.84	0.83	0.91	0.71	4.22	0.90	0.91	0.95	1.11	1.22	5.14	7.33	80.39
ICP 7035	74.67	1.50	0.91	1.10	1.04	0.75	5.30	1.15	1.13	1.02	1.04	1.08	5.40	3.67	68.87
Control															
ICPL 332(R)	68.60	0.84	0.91	1.29	0.90	0.71	5.46	0.84	0.91	0.91	0.75	0.91	4.31	3.33	71.40
ICPL 87 (S)	73.07	1.49	1.12	1.3	0.87	0.75	5.52	1.32	1.25	1.33	0.92	1.25	6.05	8.33	57.14
F Prob.	0.001	0.01	0.08	0.00	0.02	<0.00	0.01	0.03	0.04	0.01	0.01	0.01	<.001	0.00	0.004
LSD at 5%	20.63	0.43	0.22	0.24	0.23	0.14	0.14	0.31	0.26	0.22	0.21	0.20	0.14	2.64	17.28
CV(%)	16.30	23.50	13.10	13.40	14.80	10.90	25.5	18.60	14.50	12.10	12.40	10.80	10.80	23.40	15.70

R - Resistant check and S - Susceptible check

* Pod damage Rating (1 =<10% pods damaged and 9 = >80% pods damaged)

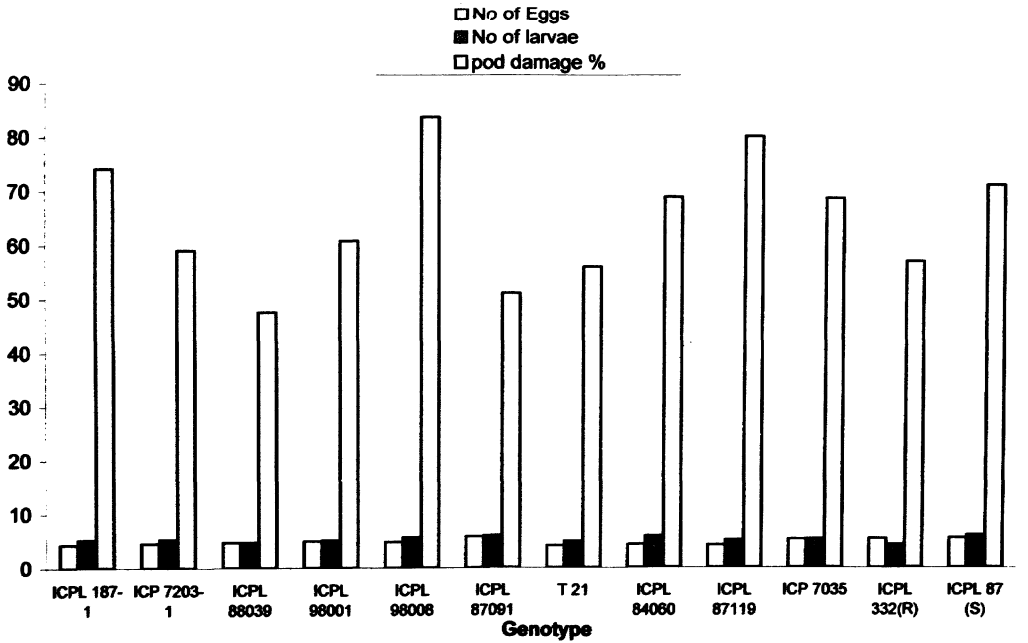


Fig.2: Number of *H.armigera* eggs, larvae and pod damage in 12 pigeonpea genotypes second planting (2000-2001)

Table 6: Number of *H. armigera* eggs, larvae and pod damage in 12 pigeonpea genotypes in rainy season first planting (2001-2002)

Genotype	No. of Flowers per plant	Eggs inflorescence^{-1}					Total eggs	Larvae inflorescene^{-1}					Total larvae	* Pod damage rating	Pod borer Damage (%)
		5th day	7th day	9th day	20th day	30th day		5th day	7th day	9th day	20th day	30th day			
ICPL 187-1	88.47	2.83	1.11	0.75	0.25	0.09	5.03	0.88	1.51	12.00	0.96	0.36	4.91	4.00	43.75
ICP 7203-1	80.50	2.01	1.42	0.52	0.83	0.33	5.12	0.50	1.07	0.78	0.45	11.63	3.97	6.67	52.02
ICPL 88039	54.17	2.45	2.58	17.5	17.5	0.67	9.20	15.0	1.42	0.99	2.42	0.50	6.82	6.67	46.75
ICPL 98001	80.10	3.11	1.33	0.41	0.30	0.00	5.15	0.09	0.85	0.68	0.28	0.00	1.90	8.67	86.97
ICPL 98008	83.00	1.38	0.53	0.21	0.34	0.00	2.47	0.52	0.54	0.66	0.72	0.39	2.84	5.67	58.05
ICPL 87091	68.10	5.53	2.39	10.0	0.78	0.25	9.95	12.0	0.25	0.25	0.36	12.50	3.31	8.67	78.66
T 21	84.83	1.45	0.98	0.28	0.30	0.09	3.09	0.36	0.67	0.82	0.82	0.26	2.94	4.00	56.33
ICPL 84060	65.83	1.53	1.38	21.5	16.67	0.42	7.15	10.0	1 25	11.00	0.75	0.44	4.54	5.67	56.72
ICPL 87119	75.83	2.41	0.93	0.37	0.37	0.06	4.14	12.0	1.31	11.80	0.96	0.75	5.41	8.67	85.33
ICP 7035	80.03	1.59	0.89	0.09	0.50	0.00	2.74	0.95	1.05	10.00	0.96	0.36	4.32	8.33	69.83
Controls															
ICPL 332 (R)	90.50	3.71	2.08	11.60	0.24	0.00	7.19	19.07	3.29	21.77	2.80	0.29	10.47	4.00	55.64
ICPL 87 (S)	95.17	1.35	0.42	0.09	0.37	0.00	2.23	0.84	1.26	11.37	0.94	0.72	4.90	8.67	82.51
F Prob.	0.706	<0.001	0.007	<0.001	<0.001	0.56	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01
LSD at 5%	39.62	1.50	1.10	0.62	0.49	0.66	2.40	0.26	0.52	0.25	0.50	0.16	1.30	6.64	0.22
CV(%)	29.70	36.30	48.90	50.10	48.00	247.00	26.90	7.30	25.30	15.10	29.00	18.40	16.50	14.10	64.40

R - Resistant check and S - Susceptible check

* Pod damage Rating (1=<10% pods damaged and 9=>80% pods damaged).

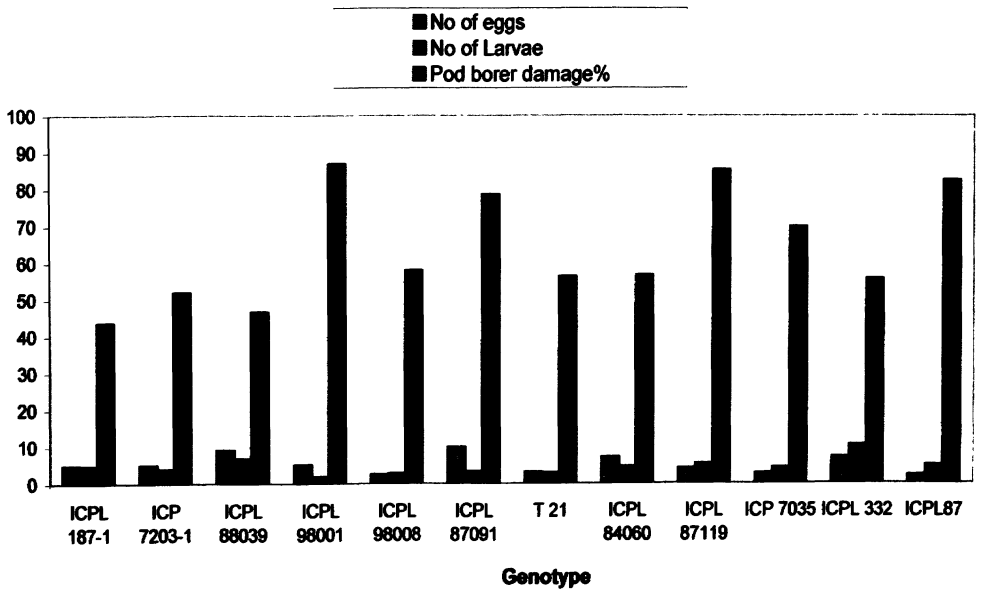


Fig.3 :Numbers of *H. armigera* eggs, larvae in 12 pigeonpea genotypes, first planting (2001-2002)

Table 7: Number of *H. armigera* eggs, larvae and pod damage in 12 pigeonpea genotypes in rainy season , second planting (2001-2002)

Genotype	No of flowers	Eggs inflorescence^{-1}					Total Eggs	Larvae inflorescene^{-1}					Total larvae	* Pod damage rating	Pod damage (%)
		5th day	7th day	9th day	20th day	30th day		5th day	7th day	9th day	20th day	30th day			
ICPL 187-1	93 83	2 12	1 32	0 90	0 49	0 00	4 84	1 06	1 30	1 30	1 25	0 95	4 71	4 88	44 98
ICP 7203-1	69 83	0 88	0 17	1 29	0 00	0 00	2 34	1 26	1 07	0 67	0 33	1 13	4 46	4 36	56 32
ICPL 88039	39 83	2 15	1 13	2 05	1 29	0 00	6 63	1 23	1 00	1 00	0 50	0 50	6 73	3 33	48 57
ICPL 98001	77 78	1 79	0 85	1 02	0 12	0 00	3 78	0 47	0 75	0 75	0 45	0 00	2 54	6 66	89 25
ICPL 98008	74 00	0 71	0 35	0 77	0 32	0 00	2 16	0 29	0 86	0 86	0 45	0 10	2 55	3 69	56 36
ICPL 87091	143 83	0 81	0 63	0 78	0 19	0 00	2 43	2 40	1 5	0 25	0 35	1 50	6 00	7 33	79 50
T 21	68 03	1 24	0 83	0 28	0 43	0 01	2 85	1 23	0 52	0 52	0 52	0 50	4 52	6 45	55 90
ICPL 84060	76 83	2 08	2 54	1 80	0 00	0 00	6 42	1 26	1 50	1 07	0 67	0 33	4 83	3 22	55 11
ICPL 87119	76 18	1 67	0 69	0 88	0 29	0 00	3 55	0 33	0 00	1 25	0 10	0 75	3 28	3 26	88 60
ICP 7035	94 78	1 71	0 52	0 97	0 08	0 00	3 03	1 17	1 21	0 95	0 95	0 31	4 59	4 54	70 86
Controls															
ICPL 332 (R)	66 83	3 16	1 48	0 92	0 36	0 00	5 94	1 40	1 85	1 85	1 75	0 85	8 10	5 69	56 69
ICPL 87 (S)	104 78	1 06	0 31	0 49	0 09	0 00	1 96	1 10	1 30	0 87	0 56	0 98	4 81	8 56	83 50
F Prob	0 00	<0 001	<0 001	<0 001	0 20	0 477	<0 001	<0 001	0 00	0 00	0 00	0 00	<0 001	<0 001	<0 001
LSD at 5%	0 00	0 24	0 22	0 48	0 00	0 42	0 68	0 16	0 00	0 00	0 00	0 00	0 16	7 54	11 10
CV(%)	0 00	8 70	14 10	27 80	0 00	17 30	10 50	17 50	0 00	0 00	0 00	0/00	2 00	14 42	14 00

R - Resistant check and S - Susceptible check

* Pod damage Rating (1 =<10% pods damaged and 9 = >80% pods damaged)

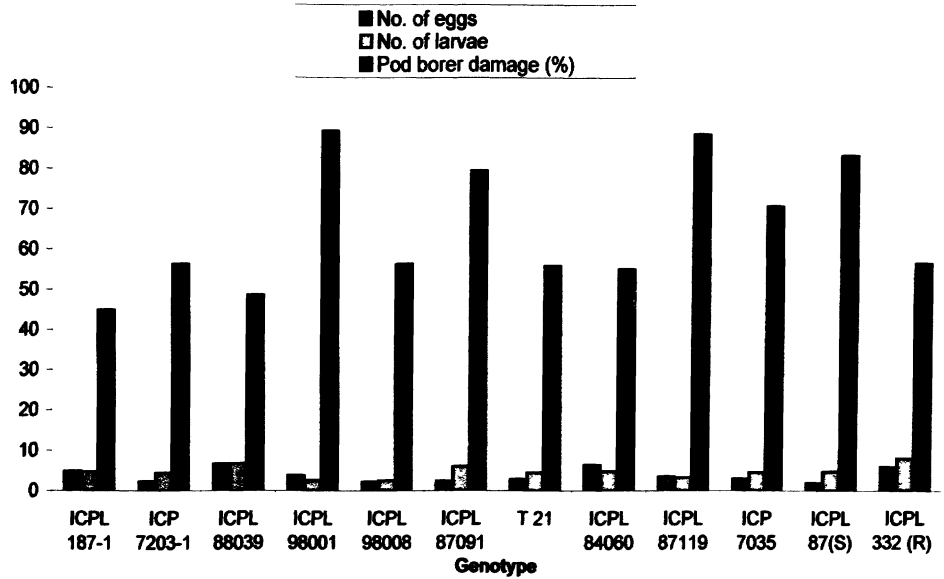


Fig.4 : Number of eggs, larvae and pod damage in 12 pigeonpea genotypes, second planting (2001-2002)

ICPL 98008 (2 55) in case of short duration genotypes In the second planting lowest number of eggs were recorded on ICPL 7035 (3 03) Lowest number of larvae were recorded on ICPL 87119 (3 28) (Table 7 and Fig 4)

4.1.2 Days to 50% flowering and days to maturity

Flowering and maturity periods were shorter in the second planting as compared to the first planting This may be because of the increased temperatures in the late sowings and photoperiod sensitivity of the genotypes tested

4.1.3 Pod damage ratings

During the 2000 rainy season, lowest pod damage rating (DR) was recorded in ICPL 88039 (2 33), ICPL 98008 (3 67), and ICP 7203-1 (4 67) among the short-duration genotypes in the first planting (Table 4) In the second planting, lowest pod damage rating was recorded in ICPL 98001 (6 00) (Table 5) During the 2001 rainy season lowest pod damage rating was recorded on T 21 (4 0) and ICPL 187-1 (4 0) in the first planting (Table 6) In case of long-duration genotypes lowest pod damage rating was recorded in ICPL 84060 (2 67), ICPL 87119 (3 00), and ICP 7035 (4 33) (Table 4) In the second planting, lowest pod damage rating was recorded in ICPL 332 (3 33) followed by ICP 7035 (3 67), ICPL 84060 (5 00) (Table 5) During the 2001 rainy season lowest pod damage rating was recorded on ICPL 332, T 21 and ICPL 187-1 (4 00) in the first planting (Table 6) In the second planting lowest pod damage rating was recorded in ICPL 84060 (3 22), followed by ICPL 87119 (3 26) (Table 7)

4.1.4 Per cent pod damage

During the 2000 rainy season first planting among the short-duration genotypes lowest pod damage was recorded in ICPL 187-1 (21.75%), followed by ICPL 87091 (22.68%) and ICPL 98001 (24.32%), ICPL 332 (31.09%) and ICP 7203-1 (34.45%) as compared to 46.02% damage in ICPL 87 in the first planting (Table 4). In case of long-duration genotypes lowest pod damage was recorded in ICPL 332 (31.09%). Pod damage per cent was more in second planting compared to 2000 rainy season first planting. Among the short duration genotypes lowest pod damage was recorded in ICPL 88039 (47.66) and higher in case of ICPL 98008 (83.85%). In case of long duration genotypes lowest pod damage per cent was recorded in ICP 7035 (68.87) (Table 5). During the 2001 rainy season first planting lower pod damage was recorded in ICP 187-1 (43.75%) followed by ICPL 88039 (46.75%) and ICP 7203-1 (52.02%) as compared to ICPL 87 (82.51%) among the short duration genotypes. In case of long duration genotypes lowest pod damage was recorded in ICPL 84060 (56.72) (Table 6). In the second planting, pod damage was lower in ICPL 187-1 (44.98%) followed by ICPL 88039 (48.57%), ICPL 7203-1 (56.32%) as compared to 83.5% damage in ICPL 87 among short duration genotypes. In case of long duration genotypes lower pod damage per cent was recorded in ICPL 84060 (55.11) (Table 7).

4.1.5 Yield and its components

4.1.5.1 100 Seed weight

During 2000-2001 first planting highest 100 seed weight was recorded in ICPL 87119 (11.44 g) followed by ICP 7035 (11.43 g) among long

duration genotypes (Table 8). In case of short duration genotypes highest 100 seed weight was recorded in ICP 7203-1 (9.85 g) followed by ICPL 87091 (9.69 g). During the second planting highest 100 seed weight was recorded in ICPL 87119 (10.70 g) followed by ICP 7035 (10.10 g) in case of long duration genotypes (Table 9). In case of short duration genotypes highest 100 seed weight was recorded in ICP 7203-1 (8.93 g) followed by ICPL 87091 (9.01 g). The 100 seed weight of the genotypes were higher during first planting compared to second planting. During 2001-2002 first planting highest 100 seed weight was recorded in ICP 7035 (11.40 g) followed by ICPL 87119 (11.00 g) among long duration genotypes (Table 10). In case of short duration genotypes highest 100 seed weight was recorded in ICPL 87091 (9.10 g). During second planting highest 100 seed weight was recorded in ICP 7035 (10.20 g) among long duration genotypes (Table 11). In case of short duration genotypes highest 100 seed weight was recorded in ICP 7203-1 (8.69 g).

4.1.5.2 Seeds per pod

ICPL 87119 and ICP 7035 had 5 seeds per pod while ICPL 332 and ICPL 98008 had 4.00 to 4.50 seeds per pod. The other genotypes had 3 00 to 3.50 seeds per pod. During 2000-2001 first planting highest seeds per pod were recorded in ICPL 87119 (5.00) followed by ICPL 84060 (4.20) among long duration genotypes. Among short duration genotypes highest seeds per pod were recorded in ICPL 98008 (4.60) followed by ICPL 98001 (3.80) (Table 8). During second planting highest seeds per pod were recorded in ICPL 98008 (4.60) among short duration genotypes. Among long duration genotypes highest seeds per pod were recorded in ICPL 87119 (5.00) (Table 9). During 2000-2001 first planting and second planting the same trend was repeated.

Table 8: Agronomic performance of 12 pigeonpea genotypes in rainy season, first planting (2000-2001)

Genotype	Days to 50% flowering	Days to maturity	Seeds per pod	100-seed weight (g)	Grain yield (tagged samples) (g)	Grain yield per 3 plants (g)	Grain yield kg ha^{-1}
ICPL 187-1	88	122	3.60	8.08	46.27	67.30	3767
ICP 7203-1	112	130	3.40	9.85	50.27	148.00	3811
ICPL 88039	70	104	3.20	8.94	18.03	105.00	1789
ICPL 98001	66	102	3.80	7.78	13.98	146.00	1046
ICPL 98008	85	120	4.60	8.21	37.13	147.00	2505
ICPL 87091	80	123	3.40	9.69	16.37	342.00	928
T 21	100	130	3.60	8.16	26.30	122.00	3017
ICPL 84060	114	154	4.20	8.88	75.33	142.00	5667
ICPL 87119	123	158	5.00	11.44	89.10	151.00	5394
ICP 7035	124	184	4.00	11.43	51.43	117.00	433
Controls							
ICPL 332 (R)	116	162	4.60	7.04	53.03	173.00	6283
ICPL 87 (S)	71	103	3.40	9.60	26.77	55.70	2567
F. Prob.	<0.001	0.00	0.00	<0.001	<0.001	0.00	<0.001
LSD at 5%	5.06	0.00	0.00	1.40	39.80	65.10	950.1
CV (%)	3.10	0.00	0.00	9.10	13.64	32.80	33.5

R - Resistant check, S - Susceptible check.

Table 9: Agronomic performance of 12 pigeonpea genotypes in rainy season, second planting (2000-2001)

Genotype	Days to 50% flowering	Days to maturity	Seeds per pod	100-seed weight (g)	Grain yield (tagged samples in g)	Grain yield 3 plants in (g)	Grain yield kg per ha
ICPL 187-1	88	122	3.60	7.87	63.43	63.70	3188
ICP 7203-1	109	130	3.40	8.93	47.60	137.00	4361
ICPL 88039	70	104	3.20	8.52	14.33	97.80	536
ICPL 98001	66	102	3.80	7.99	49.45	141.50	378
ICPL 98008	85	120	4.60	7.80	35.57	145.20	1008
ICPL 87091	80	123	3.40	9.01	17.37	41.10	418
T 21	100	130	3.60	7.54	24.90	114.80	1804
ICPL 84060	114	154	4.20	7.87	68.97	130.70	3126
ICPL 87119	123	158	5.00	10.70	85.43	145.40	2600
ICP 7035	124	184	4.00	10.10	36.77	100.80	158
Controls							
ICPL 332 (R)	117	162	4.60	6.85	52.13	167.40	4361
ICPL 87 (S)	71	103	3.40	7.17	25.12	51.80	418
F Prob.	<0.001	0	0	<0.001	0.039	0.009	< 0.001
LSD at 5%	5.91	0	0	1.06	41.74	66.73	1274.30
CV(%)	3.7	0	0	7.50	56.80	35.40	46.50

R-Resistant check, S-Susceptible check.

Table 10: Agronomic performance of 12 pigeonpea genotypes in rainy season, first planting (2001-2002)

Genotype	Days to 50% flowering	Days to Maturity	Seeds per pod	100-seed weight (g)	Grain yield (tagged samples) (g)	Grain yield per 3 plants (g)	Grain yield Kg per ha
ICPL 187-1	105	136	3.60	8.00	44.70	82.00	2992
ICP 7203-1	105	120	3.40	8.65	50.23	143.30	2514
ICPL 88039	114	128	3.20	8.90	18.03	104.10	1297
ICPL 98001	75	112	3.80	7.90	12.65	144.60	987
ICPL 98008	70	112	4.60	8.50	36.77	140.90	2241
ICPL 87091	110	160	3.40	9.10	16.37	32.20	1507
T 21	90	126	3.60	8.20	25.97	118.10	2292
ICPL 84060	115	130	4.20	9.00	73.17	128.10	3071
ICPL 87119	85	127	5.00	11.00	87.53	147.00	2851
ICP 7035	92	126	4.00	11.40	51.43	120.00	2721
Controls							
ICPL 332 (R)	70	108	4.60	7.50	49.83	136.00	3978
ICPL 87 (S)	112	135	3.40	9.00	26.43	53.70	1334
F Prob.	0	0	0	<0.001	<0.001	0.013	0.036
LSD at 5%	0	0	0	0.09	25.47	69.56	1878.90
CV (%)	0	0	0	0.80	37.30	33.32	45.60

R - Resistant check, S - Susceptible check.

Table 11: Agronomic performance 12 pigeonpea genotypes in rainy season, second planting (2001-2002)

Genotype	Days to 50% flowering	Days to Maturity	Seeds per pod	100-seed weight (g)	Grain yield (tagged samples in g)	Grain yield (per 3 plants in g)	Grain yield (kg per ha)
ICPL 187-1	80	100	3.60	7.23	63.43	63.70	2371
ICP 7203-1	95	107	3.40	8.69	46.27	130.50	1913
ICPL 88039	65	83	3.20	8.23	14.33	97.80	467
ICPL 98001	60	77	3.80	7.89	49.45	141.50	421
ICPL 98008	65	75	4.60	7.96	32.43	126.14	1904
ICPL 87091	65	92	3.40	8.09	17.37	40.30	661
T 21	88	95	3.60	6.99	22.90	110.50	1394
ICPL 84060	93	120	4.20	7.78	69.87	127.40	1828
ICPL 87119	115	125	5.00	10.02	81.17	141.00	2011
ICP 7035	112	128	4.00	10.20	34.57	99.50	3501
Controls							
ICPL 332 (R)	100	112	4.60	7.02	48.80	163.80	3501
ICPL 87 (S)	65	84	3.40	7.25	24.50	51.50	1758
F Prob.	0	0.002	0	<0.001	0.059	0.010	0.306
LSD at 5%	0	26.20	0	0.08	42.76	63.84	2385.00
CV (%)	0	15.80	0	0.60	60.10	35.00	80.80

R - Resistant check, S - Susceptible check.

4.1.5.3 Grain yield per three plants

During the 2000 rainy season grain yield per three plants was highest in ICPL 332 (173.00 g) followed by ICPL 87119 (151.00 g) among long-duration genotypes and in ICP 7203-1 (148.00 g), and ICPL 98008 (147.00 g) in the first planting among the short-duration genotypes (Table 8). In the second planting grain yield per three plants was greater in ICPL 332 (167.40 g), ICPL 87119 (145.00 g) and ICPL 84060 (130.70 g) in case of long-duration genotypes and in ICPL 98001 (141.50 g) in case of short-duration genotypes as compared to 51.80 g in ICPL 87 (Table 9). During the 2001 rainy season highest grain yield was recorded in ICPL 87119 (147.00 g) followed by ICPL 332 (136.00 g) among long-duration genotypes and in ICPL 98001 (144.60 g), ICP 7203-1 (143.30 g) in the first planting (Table 10). During the second planting higher grain yield per three plants was recorded in ICPL 332 (163.80 g) in case of long duration genotypes and ICPL 98001 (141.50 g) in case of short duration genotypes.

4.1.5.4 Grain yield per hectare

Grain yield was highest in ICPL 332 (6283 kg ha^{-1}) followed by ICPL 84060 (5667 kg ha^{-1}), ICPL 87119 (5394 kg ha^{-1}) in case of long-duration genotypes and ICPL 187-1 (3767 kg ha^{-1}), T 21 (3017 kg ha^{-1}) and ICP 7203-1 (3811 kg ha^{-1}) in case of short-duration genotypes during the 2000 rainy season in the first planting (Table 8). During the second planting highest grain yield was recorded in ICPL 332 (4361 kg ha^{-1}) followed by ICPL 84060 (3126 kg ha^{-1}) among long duration genotypes. Among the short duration genotypes highest grain yield was recorded in ICP 7203-1 (4361 kg ha^{-1}) (Table 9). During the 2001 rainy season grain yields were higher in ICPL 332 (3978 kg ha^{-1}), ICPL 84060 (3071kg ha^{-1}),

ICPL 87119 (2851 kg ha^{-1}) among long-duration genotypes and ICPL 187-1 (2992 kg ha^{-1}), ICP 7203-1 (2514 kg ha^{-1}), T 21 (2292 kg ha^{-1}) as compared to ICPL 87 in case of short-duration genotypes (Table 10). During the second planting highest grain yield was obtained in ICPL 332 (3501 kg ha^{-1}) followed by ICP 7035 (3501 kg ha^{-1}) in case of long duration genotypes. In case of short duration genotype highest grain yield was obtained in ICPL 187-1 (2371 kg ha^{-1}) (Table 11).

4.1.6 Genotypic stability for resistance to *H. armigera*

Stability statistics for yield components and pod borer resistance are presented in Tables 12, 13, 14, 15 and 16 for the 12 pigeonpea genotypes.

4.1.6.1 100 seed weight

The G x E interaction was not significant for 100 seed weight. The 100 seed weight varied from 7.00 g (ICPL 332) to 11.00 g (ICPL 87119 and ICP 7035). Among the twelve pigeonpea genotypes tested over four seasons 'b' values were significantly greater than 1 for ICP 7203-1, ICPL 87091, T 21, ICPL 87 among short duration genotypes and in ICPL 84060, ICPL 87119, ICP 7035 among long duration genotypes (Table 12).

4.1.6.2 Grain yield per plot

Grain yield per plot was significantly different due to genotype x environment (G x E) interaction among the 12 pigeonpea genotypes. Among the long duration genotypes highest grain yield per plot was recorded in ICPL 332 (2.40 kg $plot^{-1}$) but with slope 0.57 and residual mean squares δi^2 value equal to 1 indicating its unstability followed by ICPL 332. Highest grain yield per plot was

Table 12: Estimates of stability for 100 seed weight in 12 pigeonpea genotypes tested over four seasons (2000-2002)

Genotype	Mean (g)	100-seed weight			t-value
		bi	Sebi	δi^2 RMS	
ICPL 187-1	8.00	0.69	0.28	0.00	-1.10
ICP 7203-1	9.00	1.43	0.26	0.00	1.68
ICPL 88039	9.00	0.67	0.07	0.00	-4.46
ICPL 98001	8.00	-0.10	0.10	0.00	-11.50
ICPL 98008	8.00	0.43	0.18	0.00	-3.19
ICPL 87091	9.00	1.14	0.49	0.00	0.29
T 21	8.00	1.13	0.16	0.00	0.85
ICPL 84060	8.00	1.30	0.18	0.00	1.71
ICPL 87119	11.00	1.12	0.33	0.00	0.36
ICP 7035	11.00	1.39	0.28	0.00	1.38
Controls					
ICPL 332 (R)	7.00	0.3902	0.32	0.00	-1.89
ICPL 87 (S)	8.00	2.40	0.50	0.00	2.82

R – Resistant, S – Susceptible, bi = slope of regression line,
SEbi – Standard error of bi, δi^2 – Residual mean squares.

recorded in ICPL 84060 (1.91 kg plot^{-1}), but slope (0.58) and residual mean squares equal to 0 indicating its unstability. Among the short duration genotypes highest grain yield was recorded in ICPL 98001 followed by ICPL 187-1. In case of ICPL 98001 'b' value is greater than one and zero residual mean square value indicates its slight stability over the four seasons (Table 13).

4.1.6.3 Grain yield per hectare

The G x E interaction was not significant for grain yield (kg ha^{-1}) among the 12 pigeonpea genotypes tested (Table 14). Highest grain yield was recorded in ICPL 332 (4530.75 kg ha^{-1}) but slope was less than one and high residual mean square values indicating its unstability over the seasons followed by ICPL 332, highest grain yield was recorded in ICPL 84060 (2509.75 kg ha^{-1}) with slope slightly greater than one indicating its unstability. In case of short duration varieties highest grain yield was recorded in ICPL 187-1 (3423.00 kg ha^{-1}).

4.1.6.4 Pod damage ratings

The G x E interaction was not significant for pod damage ratings. Higher pod damage ratings were recorded in ICPL 98001 (7.00), ICPL 98008 (7.00), ICP 7035 (7.00) and ICPL 332 (7.00). Lowest pod damage ratings were recorded in ICPL 84060 (4.00) and ICPL 87119 (4.00). For ICPL 187-1, ICPL 84060, and T 21 the slope was slightly greater than one, indicating that there was resistance to be unstable over seasons. In ICPL 88039 the regression coefficient was <1 indicating that it is unstable in its resistance, and it will not support more larvae under higher infestation (Table 15).

Table 13: Estimates of stability of grain yield in 12 pigeonpea genotypes tested over four seasons (2000-2002)

Genotype	Grain yield (per plot)				
	Grain yield kg plot^{-1}	bi	SEbi	δi^2 RMS	t-value
ICPL 187-1	1.65	0.27*	0.22	0.00	-3.32
ICP 7203-1	1.28	0.38**	0.03	0.00	-22.30
ICPL 88039	0.46	0.23**	0.01	0.00	-75.90
ICPL 98001	1.86	1.82**	0.17	0.00	4.83
ICPL 98008	1.25	6.73**	0.75	6.00	7 64
ICPL 87091	0.17	0.14**	0.02	0.00	-40.50
T 21	1.16	0.25**	0.05	0.00	-16.30
ICPL 84060	1.91	0.58*	0.17	0.00	-2.52
ICPL 87119	1.64	0.63	0.19	0.00	-1.99
ICP 7035	0.13	0.05	0.00	0.00	-1639
Controls					
ICPL 332 (R)	2.39	0.57	0.29	1.00	-1.46
ICPL 87 (S)	0.53	0.37**	0.01	0.00	-58.70

R – Resistant, S – Susceptible, bi = slope of regression line,
SEbi – Standard error of bi, δi^2 – Residual mean squares.
*, ** Significant at P 0.05 and 0.01 respectively.

Table 14: Estimates of stability of grain yield kg per ha in 12 pigeonpea genotypes tested over four seasons (2000-2002)

Genotype	Grain yield (kg per ha)				
	Mean (kg)	bi	Sebi	δi^2 RMS	t-value
ICPL 187-1	3423.00	2.13	0.82	517360	0.30
ICP 7203-1	1914.50	0.81	0.39	-169603	0.68
ICPL 88039	787.00	0.54	0.52	-18394	0.47
ICPL 98001	3214.00	2.07	0.61	129078	0.22
ICPL 98008	1022.25	0.94	0.09	-359042	0.62
ICPL 87091	693.25	0.49	0.11	-356294	0.04
T 21	2304.00	0.71	0.52	-16883	0.63
ICPL 84060	2509.75	1.36	0.17	-332846	0.17
ICPL 87119	1816.75	1.19	0.65	2011982	0.80
ICP 7035	1503.00	0.42	1.40	2449378	0.43
Controls					
ICPL 332 (R)	4530.75	0.65	0.39	-159156	0.47
ICPL 87 (S)	3081.00	1.52	0.72	327918	0.59

R – Resistant, S – Susceptible, bi = slope of regression line,
SEbi – Standard error of bi, δi^2 – Residual mean squares.

Table 15: Estimates of stability of 12 pigeonpea genotypes tested for resistance to *H. armigera* over four seasons (2000-2002)

Genotype	Pod damage ratings (0-9 scale)				
	Mean	Bi	SEbi	δi^2 RMS	t-value
ICPL 187-1	6	1.31	1.72	2.00	0.18
ICP 7203-1	6	1.12	2.05	3.00	0.06
ICPL 88039	5	0.91	4.03	10.00	-0.02
ICPL 98001	7	-0 87	3.25	7.00	-0.57
ICPL 98008	7	-0.87	3.25	7.00	-0.57
ICPL 87091	6	3.35	1.87	2.00	1.26
T 21	6	1.33	3.42	7.00	0.10
ICPL 84060	4	-2.92	0.28	0.00	-13.90
ICPL 87119	4	-2.54	0.25	0.00	-14.20
ICP 7035	7	3.92	2.03	3.00	1.44
Controls					
ICPL 332 (R)	7	3.92	2.03	3.00	1.44
ICPL 87 (S)	6	3.35	1.87	2.00	1.26

R – Resistant, S – Susceptible, bi = slope of regression line,
SEbi – Standard error of bi, δi^2 – Residual mean squares.

4.1.6.5 Per cent pod damage

All the genotypes were unstable in their reaction to *H. armigera* in terms of per cent pod damage (Table 16). However, the regression coefficient was less than unity in case of ICPL 187-1, ICP 7203-1, ICPL 88039, ICPL 98008, T 21, and ICPL 87 had regression coefficient greater than unity and these genotypes suffered greater pod damage with an increase in intensity of infestation. Highest pod damage was observed in ICPL 87119 (78%) and lowest in ICPL 332 (50%) in case of long duration genotypes Among short duration genotypes highest pod damage was observed in ICPL 87 (74%) and ICPL 98001 (72%) and lowest in case of ICPL 187-1 (39%).

4.2 MECHANISMS OF RESISTANCE TO *H. armigera* IN PIGEONPEA

4.2.1 Antixenosis for oviposition

4.2.1.1 Oviposition non-preference under no-choice conditions

There was a considerable variation in the oviposition preference of the female moths towards the pigeonpea genotypes tested. Under no- choice cage conditions, the moths laid an average of 97 to 381 eggs per female (Table 17 and Fig.5). Among the genotypes tested there were 176 eggs per female on ICPL 332 (resistant check) compared to 381 eggs on ICPL 87 (susceptible check). Among the short duration genotypes lowest numbers of eggs 97 eggs per female were recorded on T 21 followed by 137.60 eggs on ICPL 98008. Among the long-duration genotypes, lowest numbers of eggs were recorded on ICPL 84060 (133 eggs per female), followed by ICP 7035 (200 eggs) and ICPL 87119 (240 eggs). The genotypes ICPL 87091, ICPL 87119 were preferred as substrate for oviposition while ICPL 87 was highly preferred for oviposition by the *H. armigera* females.

Table 16: Stability of resistance based on percentage pod damage to *H. armigera* in 12 pigeonpea genotypes tested over four seasons (2000-2002)

Genotype	Mean	Pod damage (%)			
		bi	Sebi	δi^2 RMS	t-value
ICPL 187-1	39	0.81**	0.00	0.00	-66.70
ICP 7203-1	49	0.70**	0.08	4.00	-3.77
ICPL 88039	47	0.11**	0.04	1.00	-21.60
ICPL 98001	72	2.30**	0.02	0.00	61.70
ICPL 98008	53	0.65**	0.06	2.00	-5.58
ICPL 87091	65	2.04**	0.05	1.00	22.00
T 21	55	0.14**	0.02	0.00	-57.10
ICPL 84060	52	0.71**	0.02	0.00	-16.20
ICPL 87119	78	1.24**	0.04	1.00	6.43
ICP 7035	63	1.06**	0.01	0.00	6.12
Controls					
ICPL 332 (R)	50	0.90**	0.00	0.00	-21.30
ICPL 87 (S)	74	1.34	0.02	0.00	16.50

R – Resistant, S – Susceptible, bi = slope of regression line,
SEbi – Standard error of bi, δi^2 – Residual mean squares.
** Significant at P 0.01

Table 17: Relative ovipositional preference by the *H. armigera* females towards 12 pigeonpea genotypes under no-choice cage conditions (2000-2002)

Genotype	No. of eggs laid Female^{-1}	ROP (%)
ICPL 187-1	153.00 (12.30±0.39)	-42.65
ICP 7203-1	171.00 (13.07±0.39)	-38.00
ICPL 88039	162.00 (12.7±0.39)	-40.29
ICPL 98001	153.00 (12.36±0.29)	-42.65
ICPL 98008	137.60 (12.36±0.11)	-46.89
ICPL 87091	240.00 (15.49±0.32)	-22.65
T 21	97.00 (9.84±0.13)	-59.38
ICPL 84060	133.00 (11.53±0.17)	-48.21
ICPL 87119	240.00 (15.49±0.32)	-22.70
ICP 7035	200.00 (14.14±0.15)	-31.11
Controls		
ICPL332 (R)	176.00 (13.26±0.19)	-36.76
ICPL87 (S)	381.00 (19.50±0.20)	

R - Resistant check, S - Susceptible check,
ROP - Relative oviposition preference in relation to ICPL 87.

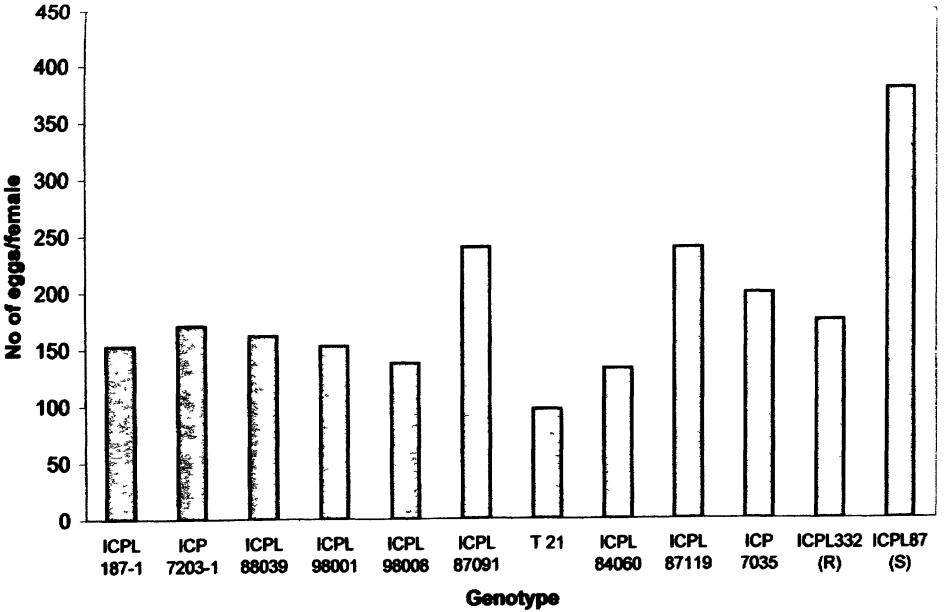


Fig.5 : Oviposition preference by *H. armigera* towards 12 pigeonpea genotypes under no-choice conditions

4.2.1.2 Oviposition non-preference under dual- choice conditions

Under dual-choice cage conditions significantly less number of eggs were laid on ICPL 187-1 (48.80), ICPL 84060 (37.27), ICPL 87119 (43.93) and ICPL 332 (56.53) as compared to the susceptible cultivar ICPL 87. The relative oviposition preference for all the test cultivars was lower than ICPL 87 under no-choice, dual-choice and multi-choice conditions (Table 18 and Fig.6).

4.2.1.3 Oviposition non-preference under multi-choice conditions

Under the multi-choice cage conditions, the female moths laid on an average 91.67 (ICPL 332) to 272.33 (ICPL 87) eggs on 12 genotypes of pigeonpea. Among the short-duration genotypes lowest numbers of eggs were laid on ICPL 98001 (113.33) followed by T 21 (131.67), ICPL 88039 (160.00), ICP 7203-1 (163.33). The genotypes ICPL 87 (272.33), ICPL 98008 (240.33) and ICPL 87091 (208.33) were highly preferred for oviposition by the *H. armigera* females under multi-choice cage conditions. Among the long-duration genotypes lowest numbers of eggs were laid on ICPL 84060 (133.33) and ICP 7035 (196.67) were highly preferred for oviposition. Relative oviposition preference in relation to ICPL 87 was negative for all the genotypes tested (Table 19 and Fig.7).

4.2.2 Antibiosis mechanism of resistance to *H. armigera*

4.2.2.1 Growth and survival of *H. armigera* on leaves of different pigeonpea genotypes

The mean larval weight on the leaves at 5 days after initiating the experiment were higher on ICP 7035 (3.8 mg) and ICPL 332 (3.8 mg) among the

Table 18: Relative oviposition preference by the *H. armigera* females towards 12 pigeonpea genotypes under dual choice cage conditions (2000-2002)

Genotype	Total number of eggs laid		t-Value	ROP
	Test genotype	ICPL 87		
ICPL 187-1	48.8[a]	74.27[b]	2.41	-20.70
ICP 7203-1	39.33[a]	48.27[a]	1.03	-10.21
ICPL 88039	31.60[a]	41.00[a]	1.22	-12.95
ICPL 98001	19.93[a]	27.80[a]	1.17	-16.49
ICPL 98008	79.33[a]	105.00[a]	1.72	-13.93
ICPL 87091	65.20[a]	64.00[a]	0.06	0.93
T 21	48.40[a]	75.73[a]	1.69	-22.02
ICPL 84060	37.27[a]	64.67[b]	2.12	-26.88
ICPL 87119	43.93[a]	73.67[b]	22.33	-25.29
ICP 7035	67.13[a]	83.60[b]	1.55	-10.93
Control				
ICPL332 (R)	56.53[a]	89.33[b]	2.29	-22.49

* Significant at P=0.050; R = Resistance check;
ROP = Relative oviposition preference in relation to ICPL 87.

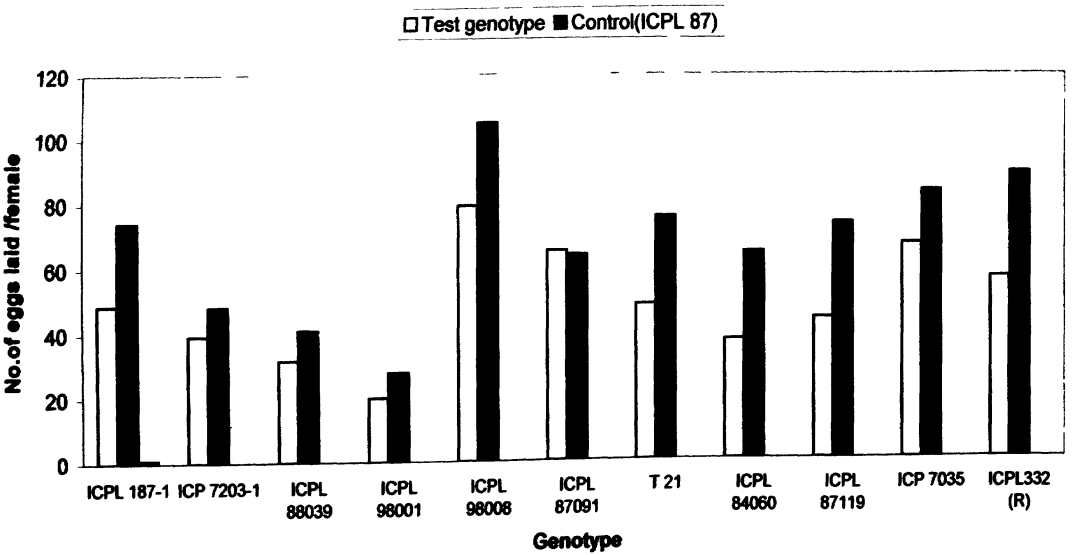


Fig.6: Oviposition preference by *H. armigera* towards 12 pigeonpea genotypes under dual-choice conditions

Table 19: Relative ovipositional preference by the *H. armigera* females towards 12 pigeonpea genotypes under multi choice conditions (2000-2002)

Genotype	No. of eggs laid Female^{-1}	ROP
ICPL 187-1	172.67(13.09±0.85)	-22.40
ICP 7203-1	163.33(12.77±0.85)	-25.02
ICPL 88039	160.00(12.60±0.85)	-25.98
ICPL 98001	113.33(10.47±0.85)	-41.22
ICPL 98008	240.33(15.49±0.85)	-6.24
ICPL 87091	208.33(14.32±0.85)	-13.32
T 21	131.67(11.44±0.85)	-34.93
ICPL 84060	133.33(11.35±0.85)	-34.26
ICPL 87119	170.00(13.03±0.85)	-23.13
ICP 7035	196.67(14.01±0.85)	-16.13
Controls		
ICPL 332 (R)	91.67(9.56±0.85)	-49.63
ICPL 87 (S)	272.33(16.49±0.85)	

R - Resistant check, S - Susceptible check,
ROP - Relative oviposition preference in relation to ICPL 87.

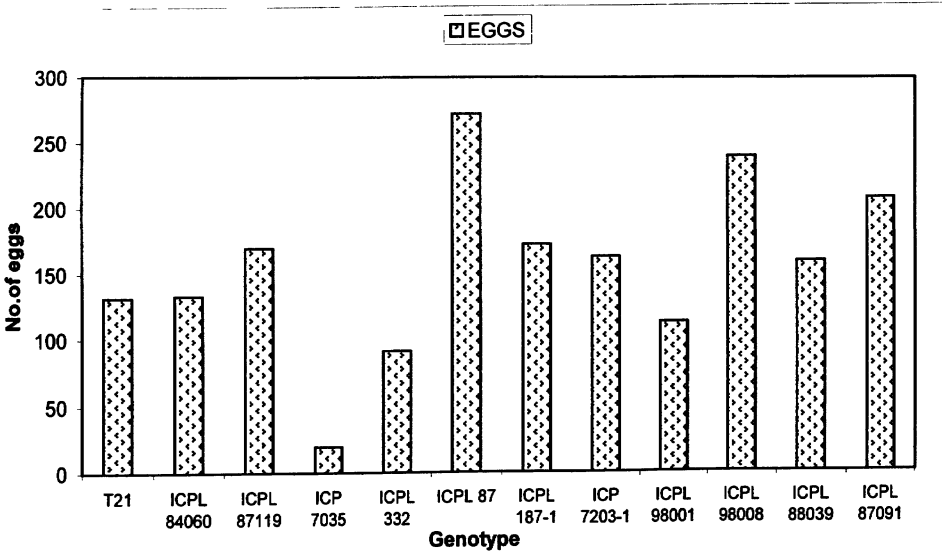


Fig.7 : Oviposition preference by *H.armigera* towards 12 pigeonpea genotypes under multi-choice conditions

long duration genotypes. In case of short duration genotypes highest larval weights were recorded on T 21 (4.6 mg) and ICPL 187-1 (4.8 mg) (Table 20).

The mean larval weights on the leaves at 10 days after initiating the experiment did not differ significantly, except on ICPL 88039. Among the short-duration genotypes lowest larval weight of 70.8 mg per larva was recorded on ICPL 88039 as compared to 79.2 mg per larva on ICPL 87. The mean larval weights at 15 days after initiation of experiment did not vary among the short duration genotypes. Among the long duration genotypes higher larval weight was observed on ICPL 332 (263.9 mg) (Fig.8). Lowest pupal weights were recorded in larvae reared on T 21 (221.4 mg) and ICPL 187-1 (223.2 mg) as compared to 237.3 mg on ICPL 87. Longest larval period was recorded on ICPL 98008 (30 days), as compared to 22 days on the susceptible check, ICPL 87 and lowest pupation was noticed on ICPL 98008 (16%). In case of long duration genotypes and lowest larval weight of 80 mg per larva was recorded on ICPL 332 and lowest pupal weights were recorded in larvae reared on ICPL 87119 (182.3 mg), ICPL 84060 (191.5 mg), ICPL 332 (225.2 mg), as compared to 227.2 mg on ICP 7035 (Table 20). Longest larval period was recorded on ICPL 84060 (32 days). Longest pupal period was recorded in larvae reared on the resistant check, ICPL 332 (17 days). Lowest adult emergence was recorded on ICPL 87119 (16 %), followed by ICPL 332 (18%) and ICPL 84060 (20%) (Table 20 and Fig.8).

4.2.2.2 Growth and survival of *H. armigera* on flowers and pods of different pigeonpea genotypes

The weights of larvae at 5 days after initiation of experiment on the flowers and pods was highest in ICPL 332 (10.8 mg) in case of long duration

Table 20: Growth and development of *H. armigera* on leaves of 12 pigeonpea genotypes (2000-2002)

Genotype	Larval wt. (mg)			Larval mortality (%)			Larval period (days)	Pupal weight (mg)	Pupal period (days)	Pupation (%)		Adult emergence (%)	
	5th day	10th day	15th day	5th day	10th day	15th day							
ICPL 187-1	4.8^{bc}	86.0^{d}	239.5^{bc}	46^{a}	46^{a}	54^{abc}	27^{bc}	223.2^{f}	15^{cd}	28^{abc}	(31.58)	28^{abc}	(28)
ICP 7203-1	4.3^{abc}	55.39^{a}	218.6^{bc}	48^{a}	48^{a}	58^{abc}	29^{bc}	216.3^{d}	15^{c}	28^{abcd}	(31.28)	26^{abcd}	(26)
ICPL 88039	2.3^{a}	70.8^{bc}	225.1^{bc}	52^{a}	52^{a}	58^{abc}	29^{abc}	234.5^{j}	15^{bc}	32^{bcd}	(34 42)	32^{abcd}	(32)
ICPL 98001	3.5^{abc}	85.8^{d}	275.5^{d}	42^{a}	42^{a}	58^{abc}	26^{bcd}	227.6^{g}	14^{cd}	30^{abcde}	(32.66)	30^{abcd}	(30)
ICPL 98008	2.4^{a}	73.1^{bc}	234.5^{bc}	50^{a}	50^{a}	58^{abc}	30^{a}	230.2^{I}	14^{cd}	16^{a}	(23.02)	24^{abcd}	(24)
ICPL 87091	4.8^{bc}	80.3^{bc}	266.3^{cd}	36^{a}	36^{a}	50^{d}	23^{f}	228.3^{h}	13^{cd}	48^{c}	(43.85)	46^{c}	(46)
T 21	4.6^{bc}	87.6^{d}	219.3^{bc}	50^{a}	50^{a}	64^{a}	25^{de}	220.5^{e}	16^{ab}	20^{ab}	(26.57)	24^{abcd}	(24)
ICPL 84060	2.9^{ab}	55.39^{a}	218.6^{b}	46^{a}	46^{a}	60^{abc}	32^{a}	209.7^{b}	15^{b}	22^{abc}	(24.22)	20^{ab}	(20)
ICPL 87119	3.4^{abc}	80.8^{bcd}	248.5^{bc}	46^{a}	46^{a}	58^{abc}	27^{b}	181.7^{a}	13^{d}	28^{abcd}	(31.88)	16^{a}	(16)
ICP 7035	3.8^{abc}	79.4^{bc}	142.8^{a}	50^{a}	50^{a}	52^{bc}	27^{bc}	227.2^{h}	14^{cd}	24^{abcd}	(28.8)	22^{ab}	(22)
Controls													
ICPL 332(R)	3.8^{abc}	55.39^{a}	218.6^{bc}	48^{a}	48^{a}	54^{abc}	30^{a}	215.0^{c}	17^{a}	20^{ab}	(26.27)	18^{a}	(18)
ICPL 87 (S)	4.7^{bc}	79.2^{dc}	286.5^{d}	38^{a}	40^{a}	46^{d}	22^{f}	237.1^{kj}	14^{cd}	40^{c}	(38.53)	36^{bcd}	(36)
F. Prob.	0.163	0.001	<0.001	0.377	0.448	0.16	<0.001	0.322	<0.001	0.001	(0.013)	0.006	(0.039)
LSD at 5%	2.04	14.59	47.77	13.46	13.30	11.33	2.59	38.50	1.64	13.51	(10.6)	14.1	
CV (%)	3.7	15.90	16.10	23.0	22.60	15.9	7.5	13.7	8.8	37.90	(31.1)	41.2	(26.8)

Means followed by same letter in a column do not differ significantly at p 0.05. Number of larvae = 50
R.- Resistant check and S.- Susceptible check Figures in parenthesis are Angular transformed values.

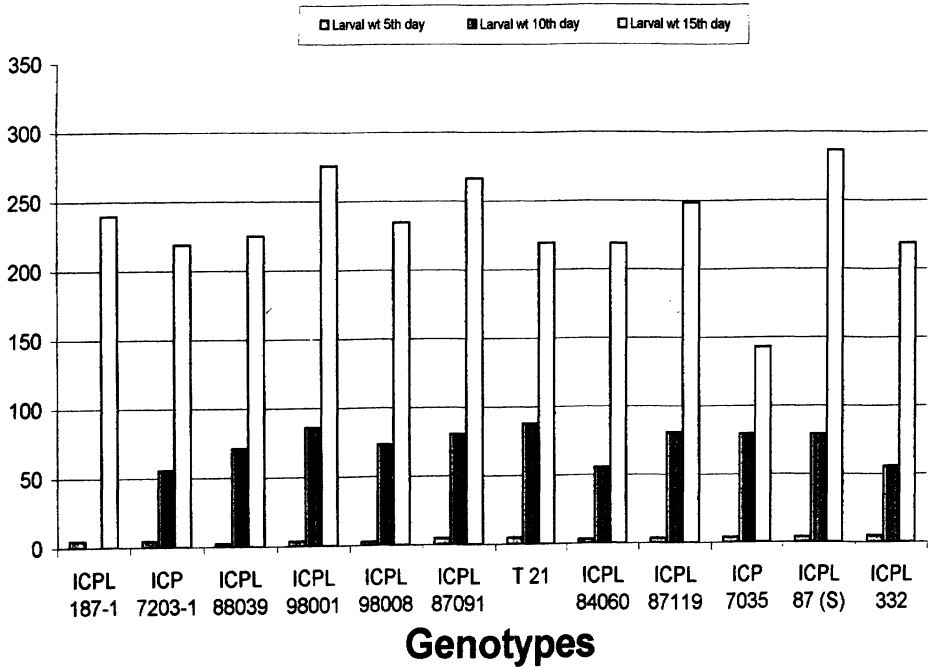


Fig. 8: Growth and development of H.armigera on leaves of 12 pigeonpea genotypes

genotypes. In case of short duration genotypes highest larval weight was recorded on ICPL 88039 (10.1 mg). Among the short-duration genotypes the weights of the larvae at 10 days after initiation of experiment on the flowers and pods of ICPL 87091 (191.50 mg), ICPL 187-1 (183.10 mg), ICPL 98008 (178.80 mg) and ICP 7203-1 (162.00 mg) were lower compared to the larvae reared on ICPL 87 (238.70 mg). Larval weight of 15 days after initiation of the experiment was highest in ICPL 87 (326.0 mg) and lowest on ICP 7203-1 (209.6 mg) among the short duration genotypes. In case of long duration genotypes lowest larval weight was recorded on ICPL 84060 (192.1 mg). Among the long duration genotypes weights of larvae at 10 days after initiation in ICPL 84060 (148.33 mg) and ICPL 332 (184.40 mg) compared to ICPL 87 (238.70 mg). Longest larval period was recorded on T 21 (24 days) followed by ICPL 98008 (23.80 days). Pupal period was relatively shorter when the larvae were reared on ICPL 88039 (9.8 days) and ICPL 87 (10.3 days). Lowest pupation and adult emergence were recorded on T 21 (38% and 24% respectively). Highest adult emergence was recorded on ICPL 87 (56%). Among the long-duration genotypes, longest larval period was recorded on ICPL 332 (24.1 days), followed by those reared on ICPL 84060 (24 days). Pupal period was 14 days on ICPL 332 (Table 21 and Fig. 9).

Correlation between pod damage parameters of larvae reared on leaves, flowers and pods of 12 pigeonpea genotypes indicated a positive and significant correlation between pupal weight and damage (0.60), pupal period and damage (0.58). Similarly positive correlation was observed between larval weight and damage (0.43) which indicates that the pod damage increases because increase in larval feeding which results in increase of larval weight (Table 22). Principal component analysis of 12 pigeonpea genotypes based on biological effects of leaf, flower and pods towards *H. armigera* revealed that ICPL 87119, T21, ICPL 187-1,

Table 21: Growth and development of *H. armigera* on flowers and pods of 12 pigeonpea genotypes (2000-2002)

Genotype	Larval wt. (gm)			Larval mortality (%)			Larval period (days)	Pupal wt. (mg)	Pupal period (days)	Pupation (%)		Adult emergence (%)	
	5th day	10th day	15th day	5th day	10th day	15th day							
ICPL 187-1	4.8^{d}	183.1^{d}	232.7^{e}	26^{c}	34^{bcd}	42^{cde}	22.5^{bcd}	212.0^{d}	12.4^{cde}	52^{e}	(46.15)	40^{bc}	(39.18)
ICP 7203-1	6.3^{h}	162.0b	209.6^{b}	24^{bc}	32^{bcd}	40^{bcd}	22.1^{bcd}	207.2^{c}	12.9^{d}	54^{f}	(47.31)	42^{bc}	(40.28)
ICPL 88039	10.1^{j}	259.9^{j}	319.3^{j}	6^{a}	14^{a}	28^{a}	18.3^{a}	300.8^{l}	9.8^{a}	66^{j}	(54.61)	58^{d}	(49.84)
ICPL 98001	5.4^{e}	193.8^{g}	252.8^{h}	24^{b}	26^{b}	32^{ab}	20.8^{abc}	234.3^{i}	11.4^{bc}	56^{g}	(48.46)	44^{bc}	(41.49)
ICPL 98008	4.8^{d}	178.8^{c}	221.0^{c}	24^{bcd}	34^{bcd}	42^{c}	23.8^{d}	203.1^{a}	12.8^{d}	52^{e}	(46.15)	38^{bcd}	(37.98)
ICPL 87091	4.2^{c}	191.5^{g}	242.2^{g}	24^{bc}	30^{bc}	40^{b}	22.3^{b}	220.7^{e}	12.1^{c}	52^{e}	(46.15)	34^{abc}	(35.11)
T 21	4.1^{b}	189.1^{f}	227.8^{d}	28^{d}	40^{d}	46^{de}	24^{d}	220.0^{f}	12.7^{d}	38^{a}	(37.15)	24^{a}	(37.15)
ICPL 84060	3.1^{a}	148.3^{a}	192.1^{a}	26^{cd}	38^{cd}	46^{de}	24^{d}	203.9^{b}	14.1^{e}	48^{c}	(43.85)	34^{abc}	(35.49)
ICPL 87119	6.2^{g}	204.4^{l}	241.5^{f}	24^{cd}	36^{cd}	50^{e}	22.5^{c}	224.7^{h}	11.6^{bcd}	44^{b}	(41.49)	32^{ab}	(34.11)
ICP 7035	7.0^{l}	223.1^{h}	304.8^{l}	14^{bc}	28^{bc}	34^{abc}	20.8^{ab}	272.5^{j}	11.1^{abc}	58^{h}	(49.67)	52^{d}	(46.15)
Controls													
ICPL 332 (R)	10.8^{k}	184.4^{e}	248.3^{g}	28^{bcd}	34^{bcd}	44^{de}	24.1^{d}	222.0^{g}	14^{e}	50^{d}	(45)	44^{bc}	(41.19)
ICPL 87 (S)	5.8^{f}	238.7^{k}	326.0^{k}	28^{bc}	30^{bc}	36^{abc}	19.3^{ab}	278.1^{k}	10.3^{ab}	60^{i}	(50.82)	56^{d}	(48.51)
F prob.	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	(46.4)	<0.001	(39.9)
LSD at 5%	2.36	37.8	35.64	11.11	7.76	8.12	2.519	34.16	1.34	11.11	(5.4)	12.4	(5.4)
CV (%)	30.5	15.1	11.1	37.9	19.4	15.9	9.0	11.5	8.7	16.1	(0.008)	23.3	(<0.001)

Means followed by same letter in a column do not differ significantly at p 0.05; Number of larvae = 50. Figures in parenthesis are Angular transformed values. R. – Resistant check and S – Susceptible check.

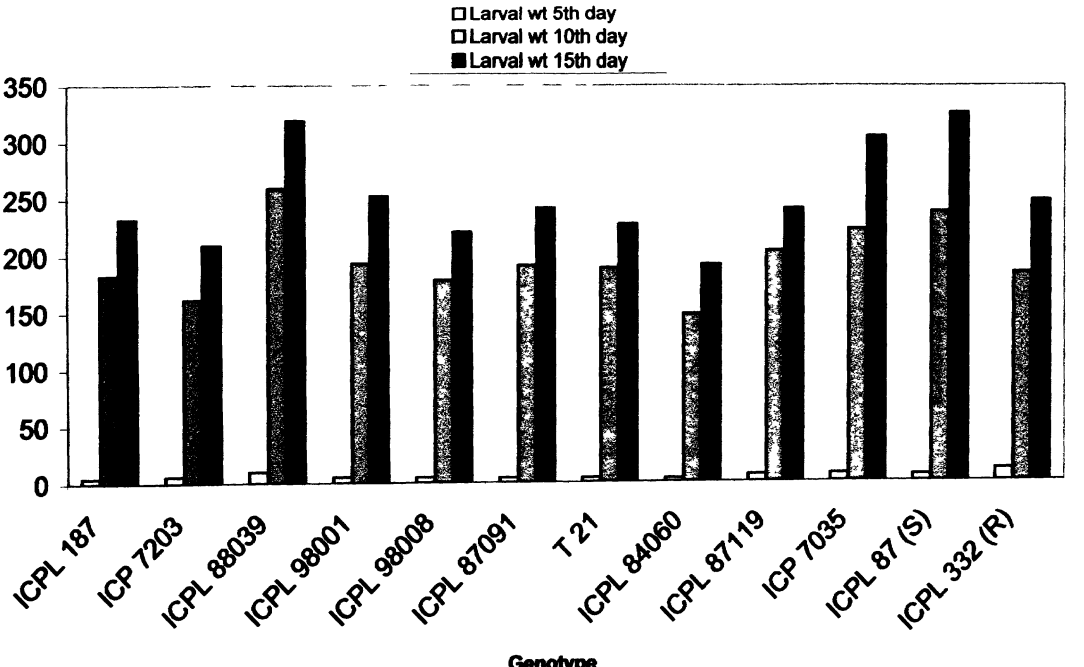


Fig. 9: Growth and development of *H.armigera* on flowers and pods of12 pigeonpea genotypes

ICPL 84060, ICP 7203-1, ICPL 98008, ICPL 332 are resistant genotypes; ICP 7035, ICPL 88039 are susceptible genotypes; ICPL 87091, ICPL 87, ICPL 98001 are moderately resistant genotypes (Fig.10).

4.2.2.3 Standardisation of artificial diet impregnated with lyophilized leaf powder of pigeonpea

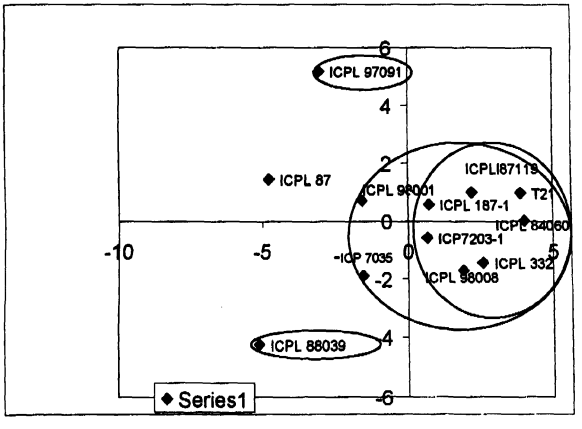
Larval mortality increased with an increase in the amount of leaf powder, and ranged between 26.67 to 60% in ICPL 332 and 16.67 to 28.33% in case of ICPL 87. There were not significant differences in larval mortality with the increase in the amount of leaf powder per 10 to 20 mg per 75ml of artificial diet, Pupal weights ranged from 296.7 to 333.1mg in case of ICPL 332 and 297.6 to 319.3 mg in case of ICPL 87 as compared to 313.7 mg in case of standard artificial diet. There was a significant prolongation of larval period when lyophilised leaf powder was added into the artificial diet and such an increase was greater for resistant cultivar ICPL 332 as compared to that of ICPL 87. Differences in the pupal period were large between the larvae reared on standard artificial diet and those reared on diets containing lyophilised leaf powder of ICPL 332 and ICPL 87. Per cent pupation was 40 to 63.3 in diets with ICPL 332 leaf powder and 56.67 to 66.67% in diet with ICPL 87 leaf powder. Similarly, the adult emergence ranged from 20 to 53.33% and 43.3 to 56.67% in ICPL 332 and ICPL 87 respectively, as compared to 60.00% in the standard artificial diet. Thus impregnation of lyophilised leaf powder resulted in significant adverse effects on larval survival, larval weight, larval period and per cent pupation and adult emergence. The differences in these parameters between the resistant and susceptible cultivars were maximum when 15 to 20 g leaf powder was impregnated into 75 ml of artificial diet. Therefore the

Table 22: Correlations between damage parameters of larvae reared on leaves, flowers and Pods, of 12 Pigeonpea genotypes (2000-2002)

Sl.No	Damage parameter	Correlation value
1	Larval weight	0.43
2	Larval mortality on 10^{th} day	0.07
3	Pupal weight	0.60*
4	Pupal period	0.58*
5	Adult emergence percentage	0.24
6	Pupation percentage	0.40

Significantly different at 5% probability.

Fig 10: Principal component analysis of 12 pigeonpea genotypes based on biological effects of leaves, flowers and pods towards *H. armigera*



technique can be used to measure the antibiosis component of resistance to *H. armigera* in pigeonpea (Table 23 and Fig.11).

4.2.2.4 Standardisation of artificial diet impregnated with lyophilised pod powder of pigeonpea

Larval mortality increased with an increase in the amount of pod powder, and ranged between 15 to 33.30% in ICPL 332 and 8.83 to 13.33 % in case of ICPL 87. However, there was no significant difference in larval mortality with the increase in the amount of pod powder of ICPL 87 from 10 to 20 g in artificial diet, pupal weights ranged from 159 to 284.20 mg in case of ICPL 332 and 191.9 to 293.20 mg in case of ICPL 87 as compared to 276.40 mg in case of standard artificial diet. Highest pupation percentage (63.33) and highest adult emergence (53.30) was observed at 5 g concentration in case of ICPL 332. Highest pupation percentage (73.33) was observed at 5 g concentration in case of ICPL 87. Highest adult emergence (53.33) was observed at 5 g concentration in case of ICPL 87 (Table 24 and Fig.12). The differences in these parameters between the resistant and susceptible cultivars were maximum when 15 to 20 g leaf powder was impregnated into 500 ml of artificial diet (Table 24).

4.2.2.5 Growth and survival of *H. armigera* on lyophilized leaf powder impregnated in artificial diet of different pigeonpea genotypes

The weight of 10 day-old-larvae reared on diets impregnated with lyophilized leaf powder of 12 pigeonpea genotypes differed significantly. Among the long-duration genotypes lowest larval weight was recorded in larvae reared on ICP 7035 (11.50 mg). The larvae reared on artificial diet containing leaf powder of

Table 23: Standardization of artificial diet impregnated with lyophilized leaf powder of pigeonpea for assessing antibiosis to *H. armigera* (2000-2002)

Genotype (**)	Larval Wt. (10 DAI)	Larval mortality % (10 DAI)		Pupal wt. (mg)	Larval period (days)	Pupal period (days)	Pupation (%)		Adult emergence (%)	
Resistant check										
ICPL 332 5	257 8^{f}	26 67^{cd}	(30 79)^{cd}	333 1^{e}	22^{cde}	9^{a}	63 33^{b}	(53 07)	53 33^{bc}	(47 01)
ICPL 332 10	50 1^{c}	50 00^{ab}	(45 00^{ab})	298 9^{a}	28^{a}	11^{bcd}	40 00^{a}	(39 23)	20 00^{a}	(26 07)
ICPL 332 15	30 7^{b}	60 00^{a}	(50 85^{a})	296 7^{a}	25^{bc}	11^{bcde}	66 67^{bc}	(54 99)	36.67^{abc}	(37 4)
ICPL 332 20	18 1^{a}	60 00^{a}	(50 85^{a})	300 0^{abcd}	27^{ab}	12^{ce}	56 67^{ab}	(49 22)	33 33^{ab}	(34 93)
Susceptible check										
ICPL 87 5	295 7^{g}	28 33^{c}	(32 09^{c})	319 3^{bcde}	16^{defg}	10^{b}	66 67^{bc}	(54 78)	56 67^{cd}	(48 85)
ICPL 87 10	211 9^{e}	28 33^{c}	(32 09^{c})	299 7^{abc}	17^{f}	12de	56 67^{ab}	(48 85)	43 33^{bc}	(41 07)
ICPL 87 15	102 6^{d}	18 33^{c}	(25 31^{cde})	339 8^{c}	20de	12^{bde}	66 67^{b}	(55 07)	50 00^{bcd}	(44 92)
ICPL 87 20	147 4^{d}	16 67^{c}	(23 86^{cde})	297 6^{ab}	18de	11^{bc}	63 33^{bc}	(53 07)	53 33^{bcd}	(47 01)
Standard diet	388 3^{h}	6 67^{d}	(12 29^{f})	313 7^{abcdef}	14^{f}	11^{bcde}	66 67^{bc}	(54 78)	60 00^{d}	(50 77)
F Prob	<0 001	<0 001	(<0 001)	0 005	<0 001	0 003	0 036	(0 259)	<0 001	(0 015)
LSD at 5%	17 29	14 64	(14 07)	23 32	4 29	1 318	15 62	(17 7)	14 94	(17 67)
CV(%)	2 6	25 8	(17 8)	4 3	12 0	7 0	14 9	(14 7)	19 1	(17 9)

Means followed by same letters in a column do not differ significantly at P 0 05, Number of larvae = 50 DAI = Days after initiation
Figures in parenthesis are angular transformed values ** Amount of lyophilized pod powder added to artificial diet (65 gm)

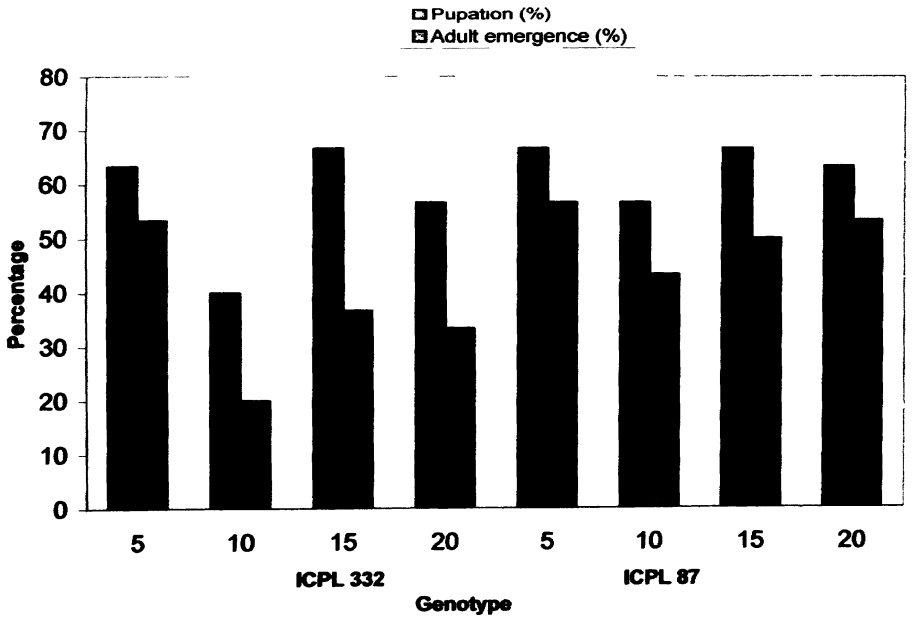


Fig.11: Standardisation of artificial diet impregnated with lyophilised leaf powder of pigeonpea for assessing antibiosis to *H. armigera*

Table 24 Standardization of artificial diet impregnated with lyophilized pod powder of pigeonpea for assessing antibiosis to *H armigera* (2000-2002)

Genotype (**)	Larval Wt (10 DAI)	Larval mortality % (10 DAI)		Pupal wt (mg)	Larval period (days)	Pupal period (days)	Pupation (%)		Adult emergence (%)	
Resistant check										
ICPL 332 5	77 7^{f}	15 00^{d}	22 79^{cd})	284 2^{d}	15 67	8 50^{d}	63 33^{b}	53 07^{cd}	53 3^{bc}	47 0
ICPL 332 10	50 9^{e}	19 97^{c}	(26 37^{bc})	247 6^{c}	24 33^{ab}	10 83^{bc}	40 00^{a}	39 23^{a}	20 0^{a}	26 1^{a}
ICPL 332 15	7 8^{ab}	26 63^{b}	(30 99^{ab})	161 8^{a}	22 37^{bc}	10 33^{ab}	43 33^{a}	41 07^{ab}	33 3^{ab}	34 9^{abc}
ICPL 332 20	5 2^{a}	33 30^{a}	(35 24^{a})	159^{a}	25 17^{a}	9 78^{cd}	43 33^{ab}	41 15^{ab}	33 3^{ab}	34 9^{abc}
Susceptible check										
ICPL 87 5	68 5^{ef}	8 83^{f}	(17 05^{def})	293 2^{d}	14 67^{e}	10 17^{a}	73 33^{b}	59 00^{cde}	53 3^{c}	46 9^{cde}
ICPL 87 10	48 1^{d}	2 20^{f}	(4 96^{b})	249 6^{c}	16 00^{e}	11 67^{a}	60 00^{b}	60 77^{c}	43 3^{bc}	41 1^{bcd}
ICPL 87 15	18 8^{abc}	11 07de	(19 22de)	226 4^{bc}	19 00^{d}	10 83^{bc}	66 67^{bc}	55 07^{cde}	50 0^{bc}	44 9^{bcde}
ICPL 87 20	9 8^{abc}	13 3^{c}	(21 39^{c})	191 9^{ab}	20 67^{cd}	11 17^{ab}	40 00^{a}	39 15^{a}	30 0^{a}	33 0^{ab}
Standard diet	301 2	10 00^{d}	(18 43^{def})	276 4^{d}	12 33^{f}	9 50^{c}	73 33^{bc}	50 00^{cde}	60 0^{d}	50 8de
Mean	0 065	15 59	(15 59)	0 2322	18 91	10 31	55 90	48 6	41 9	40 0
F Prob	<0 001	<0 001	(<0 001)	<0 001	<0 001	0 005	<0 001	<0 001	0 002	0 01
LSD at 5%	14 78	6 29	(5 72)	33 55	2 71	1 34	15 40	16 15	17 39	12 28
CV(%)	13 1	23 3	(22 5)	8 3	8 3	7 5	16 90	16 7	24 0	18 8

Means followed by same letters do not differ significantly Number of larvae – 30 DAI = Days after initiation
Figures in parenthesis are angular transformed values ** Amount Lyophilised pod powder added to artificial diet (65 gm)

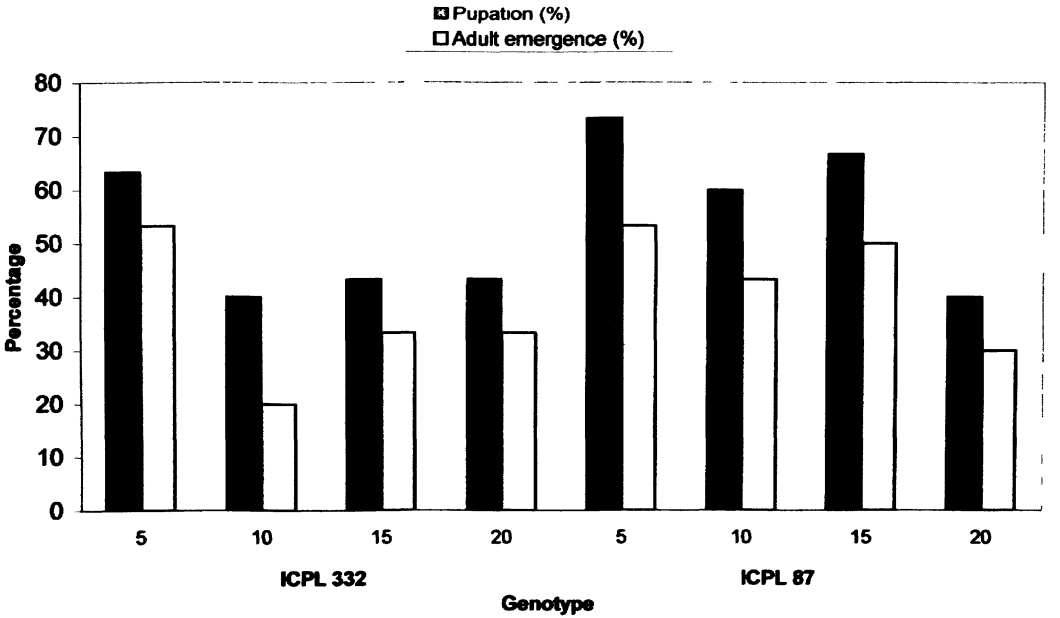


Fig.12: Standardistion of artificial diet impregnated with lyophilised pod powder of pigeonpea for assesing antibiosis to *H. armigera*

ICPL 87119 (14.84 mg), and ICPL 332 (41.53 mg). Lowest pupal weight was recorded in larvae reared on ICPL 84060 (245.9 mg), followed by ICPL 87119 (249.5 mg); and ICPL 332 (311mg). Longest larval period was recorded in larvae reared on ICPL 332 (30.84 days), followed by those reared on ICPL 84060 (29.83 days). The pupal period was 14 days on ICPL 84060, followed by 12.70 days on ICPL 332. Lowest pupation was recorded on ICPL 332 (40.00%), followed by ICPL 84060 (33.33%). Similarly, lowest adult emergence was recorded on artificial diet containing lyophilized leaf powder of ICPL 84060 (20.00%)

Among the short-duration genotypes highest larval weight was recorded in larvae reared on ICPL 98008 (44.32 mg). The larvae reared on artificial diet containing leaf powder of ICPL 187-1 (15.55 mg), ICPL 88039 (21.59 mg), ICPL 98001 (28.43 mg), weighed significantly lower than the larvae reared on artificial diet containing leaf powder of ICPL87 (51.87 mg). There were significant differences in the pupal weights of larvae reared on the artificial diet containing lyophilised leaf powder of different genotypes. Highest pupal weight was recorded on ICPL 88039 (332.90 mg), followed by ICPL 87091 (332.60 mg). Longest larval period was recorded in larvae reared on ICPL187-1 (27.67 days) and ICP 7203-1 (25.42 days). The pupal period was 13 days on ICPL 187-1 and 12 days on T 21. Larval survival was greater on diets containing lyophilized pod powder than the diets containing lyophilized leaf powder (Table 25).

4.2.2.6 Growth and survival of *H. armigera* on lyophilized pod powder impregnated in artificial diet of different pigeonpea genotypes

Among the short-duration genotypes when the larvae were reared on the lyophilized pod powder larval weights were greater (Table 26) in larvae reared

Table 25: Growth and development of *H. armigera* on artificial diet impregnated with 10 g of lyophilized leaf powder of 12 pigeonpea genotypes (2000-2002)

Genotype	Larval wt 10DAI (mg)	Pupal wt (mg)	Larval mortality (%)		Larval period (days)	Pupal period (days)	Pupation (%)		Adult emergence (%)	
Artificial diet	210.15 ^{h}	371.40 ^{m}	0.00 ^{a}	(68.07 ^{a})	20.18 ^{cd}	9.83 ^{c}	80.00 ^{d}	(68.07^{c})	76.67^{e}	(61.92 ^{c})
ICPL 187-1	15.55 ^{ab}	329.30 ^{h}	6.67 ^{a}	(40.86 ^{b})	27.67 ^{abc}	13.00 ^{ab}	43.33^{abc}	(40.86 ^{ab})	36.67^{abc}	(36.93 ^{abc})
ICPL 7035	11.50 ^{a}	279.80 ^{d}	3.33 ^{a}	(48.85 ^{b})	23.33 ^{abc}	11.17 ^{bc}	56.67^{abc}	(48.85 ^{ab})	50.00 ^{bc}	(45.00^{bcd})
ICPL 7203-1	36.17 ^{e}	328.40 ^{k}	6.67 ^{a}	(51.14^{ab})	25.42^{bcd}	12.17 ^{b}	60.00^{a}	(51.14 ^{ab})	50.00 ^{bc}	(45.00 ^{bcd})
ICPL 84060	32.38 ^{d}	245.90 ^{a}	10.00 ^{a}	(35.22 ^{c})	29.83 ^{ab}	14.00^{a}	33.33 ^{bc}	(35.22 ^{a})	20.00 ^{a}	(26.07 ^{a})
ICPL 87091	28.75 ^{cd}	332.60 ^{j}	0.00 ^{a}	(51.14^{ab})	25.00^{ab}	10.33 ^{bc}	60 .00^{a}	(51.14 ^{ab})	60.00 ^{d}	(50.77 ^{d})
ICPL 87119	14.84 ^{ab}	249.50 ^{b}	3.33 ^{a}	(49.22 ^{b})	26.5^{ab}	12.33 ^{ab}	56.67 ^{bc}	(49.22 ^{b})	50.00 ^{bcd}	(45.08 ^{bc})
ICPL 88039	21.59 ^{bc}	332.90 ^{k}	0.00 ^{a}	(52.78^{ab})	21.3^{c}	12.33 ^{a}	63.33 ^{bc}	(52.78 ^{ab})	56.67 ^{d}	(48.85 ^{d})
ICPL 98001	28.43 ^{cd}	331.70 ^{i}	6.67 ^{a}	(53.07^{ab})	17.85^{e}	11.17 ^{bc}	63.33 ^{bc}	(53.07 ^{b})	53.33 ^{c}	(46.92 ^{bc})
ICPL 98008	44.32 ^{f}	327.30 ^{g}	0.00 ^{a}	(46.92 ^{b})	18.37 ^{c}	11.17 ^{bc}	53.33 ^{bc}	(46.92 ^{ab})	46.67 ^{cd}	(43.08 ^{bc})
T21	32.38 ^{d}	321.80 ^{f}	3.33 ^{a}	(50.8 ^{ab})	24.09 ^{a}	12.00 ^{a}	60 .00^{bc}	(50.85 ^{ab})	50.00 ^{cd}	(45.00 ^{bc})
Controls										
ICPL332(R)	41.53 ^{f}	311.00 ^{e}	13.33 ^{a}	(38.86 ^{b})	30.84 ^{a}	12.70^{a}	40.00^{ab}	(38.86 ^{a})	33.33 ^{ab}	(35.01 ^{ab})
ICPL87(S)	51.87 ^{g}	261.60 ^{c}	3.33 ^{a}	(52.78 ^{ab})	21.67 ^{b}	10.50 ^{b}	63.33 ^{bc}	(52.78 ^{ab})	63.33 ^{d}	'(52.78 ^{d})
Fprob	<0.001	0.064	0.214	0.101	0.013	0.003	0.147	0.101	<0.001	<0.001
Lsd	24.63	77.60	10.12	17.58	7.04	1.80	27.33	17.58	19.60	11.96
cv %	33.40	14.90	137.9	2.12	17.4	9.1	28.8	2.12	23.40	15.9

DAI: Days after initiation of experiment. Figures followed by same letter within a column do not differ significantly at P 0.05 .
R: Resistant and S: Susceptible. Figures in parenthesis are angular transformed values.

Table 26: Growth and development of *H. armigera* on artificial diet impregnated with 10 g of lyophilized pod powder of different pigeonpea genotypes (2000-2002)

Genotype	Larval wt 10 DAI (mg)	Pupal wt (mg)	Larval mortality (%)		Larval period (days)	Pupal period (days)	Pupation (%)		Adult emergence (%)	
			Actual	Angular			Actual	Angular	Actual	Angular
Artificial diet	387.50 ^{m}	329.00 ^{m}	0.00 ^{b}	(0.00)	16.17 ^{d}	8.83 ^{c}	90.00 ^{c}	(71.570	86.67 ^{e}	(68.86)
ICPL 187-1	146.80 ^{h}	232.30 ^{e}	16.67 ^{a}	(19.93)	20.50 ^{b}	12.00 ^{a}	60.00 ^{a}	(50.85)	53.30^{abc}	(46.92)
ICPL 7035	138.30 ^{g}	292.8 ^{l}	13.33 ^{a}	(21.14)	18.67 ^{c}	11.33 ^{b}	66.67 ^{ab}	(54.78)	50.00 ^{a}	(45.000
ICPL 7203-1	156.00^{l}	211.70 ^{b}	16.67 ^{a}	(23.86)	20.17 ^{b}	11.50 ^{ab}	70.00 ^{ab}	(57.00)	46.67 ^{ab}	(42.990
ICPL 84060	104.20 ^{d}	215.40 ^{c}	16.67^{a}	(23.86)	22.00 ^{a}	13.50 ^{a}	70.00 ^{ab}	(56.79)	56.67 ^{ab}	(48.85)
ICPL 87091	278.90 ^{k}	206.40 ^{a}	6.67 ^{a}	(12.29)	20.50 ^{b}	11.17 ^{b}	70.00 ^{ab}	(57.00)	63.33 ^{b}	(52.78)
ICPL 87119	47.90 ^{a}	234.70 ^{f}	0.00 ^{b}	(0.00)	22.17 ^{abc}	12.33 ^{ab}	70.00 ^{ab}	(57.00)	40.00 ^{a}	(39.15)
ICPL 88039	58.10 ^{b}	281.10 ^{k}	3.33 ^{a}	(6.14)	16.00 ^{d}	9.83 ^{c}	76.67 ^{ab}	(61.22)	70.00 ^{d}	(57.00)
ICPL 98001	184.40 ^{j}	256.90 ^{h}	6.67 ^{a}	(8.86)	18.50 ^{c}	11.67 ^{ab}	80.00 ^{b}	(63.43)	66.67 ^{c}	(54.78)
ICPL 98008	84.00 ^{c}	245.90 ^{g}	6.67 ^{a}	(8.86)	20.50 ^{b}	10.83 ^{b}	70.00 ^{ab}	(57.00)	63.33 ^{b}	(53.07)
T 21	119.80 ^{e}	217.10 ^{d}	6.67 ^{a}	(8.86)	21.83 ^{b}	12.83 ^{a}	66.67 ^{ab}	(54.99)	50.00 ^{ab}	(45.00)
Controls										
ICPL 332®	131.80 ^{f}	267.60 ^{l}	13.33 ^{a}	(17.22)	24.67 ^{a}	12.50 ^{ab}	56.67 ^{a}	(48.85)	43.33 ^{a}	(41.15)
ICPL 87(S)	319.80 ^{l}	275.50 ^{j}	6.67 ^{a}	(12.29)	17.33 ^{d}	11.00 ^{b}	56.67 ^{a}	(48.93)	53.33 ^{ab}	(46.71)
Fprob	<0.001	0.061	0.297	0.174	<0.001	0.026	0.033	0.008	0.005	0.005
Lsd	110.3	69.68	15.58	19.18	2.38	2.18	17.21	10.113	19.95	12.56
cv %	39.4	16.50	20.4	91	8.60	11.30	14.7	10.6	20.7	15.1

DAI: Days after initiation. Figures followed by same letter in a column do not differ significantly at P 0.05.
R: Resistant and S: Susceptible.Figures in parenthesis are angular transformed values.

on diets containing pod powder of ICPL 87 (319.80 mg) and) followed by ICPL 88039 (58.10 mg). Lowest pupal weights were recorded on ICPL 87091 (206.40 mg) followed by ICP 7203-1 (211.70 mg), ICPL84060 (215.40 mg). Longest pupal period was recorded in larvae reared on diets containing lyophilized pod powder of T 21 (12.83 days). Lowest adult emergence was noticed in ICP 7203-1 (46.67%). Among the long-duration genotypes larval weights were lowest on ICPL 87119 (47.9 mg) and longest larval period was recorded in larvae reared on ICPL 332 (24.67 days) followed by ICPL 87119 (22.17 days). Longest pupal period was recorded in larvae reared on diets containing lyophilized pod powder of ICPL 84060 (13.5 days). When the larval were reared on artificial diet impregnated with the lyophilized leaf and lyophilized pod powder there was significant difference in the per cent pupation and per cent adult emergence. When the larvae were reared on diets containing lyophilized pod powder lowest pupation was recorded on ICPL 332 (56.67%). Fecundity and egg viability of adults emerging from larvae reared on different genotypes did not differ significantly.

Correlations between pod damage parameters of larvae reared on lyophilized leaf powder and lyophilized pod powders impregnated in artificial diet of pigeonpea genotypes indicated (Table 27) that there was a positive and significant correlation between larval weight and pod damage (0.71), larval mortality on 10^{th} day and pod damage (0.71). Adult emergence per cent and pod damage (0.55), and pupation per cent and pod damage (0.63). Principal component analysis of 12 pigeonpea genotypes based on biological effects of leaf and pod powder impregnated into artificial diet indicated that T 21, ICP 7035, ICP 7203-1, ICPL 98008, ICPL 87119 are resistant genotypes; ICPL 98001 is a susceptible

Table 27: Correlations between damage parameters of larvae reared on lyophilised Leaf powders and lyophilised pod powders impregnated in artificial diet of 12 pigeonpea genotypes (2000-2002)

Sl.No	Damage parameter	Correlation value
1	Larval weight	0.71**
2	Larval mortality on 10^{th} day	0.71**
3	Pupal weight	0.23
4	Pupal period	0.71**
5	Adult emergence percentage	0.55*
6	Pupation percentage	0.63*

* Significantly different at 5% probability.

genotype; ICPL 87, ICPL 87091, ICPL 88039, ICPL 187-1, ICP 84060 are moderately resistant genotypes (Fig.13).

4.2.2.7 Larval feeding on inflorescences of 12 pigeonpea genotypes

The growth of neonate larvae of *H. armigera* on inflorescences of 12 pigeonpea genotypes was observed under laboratory conditions. Highest larval mortality was observed on ICPL 332 (56.67%) followed by ICP 7035 (50.00%) among long-duration genotypes and in ICPL 88039 (40.00%) and ICPL 98001 (40.00%) in case of short-duration genotypes. Highest weight gain was observed on ICP 7035 (133.14%) and there was no significant difference among the short duration genotypes (Table 28).

4.2.3 Trichome types and their density in 12 pigeonpea genotypes

Five morphologically distinct types of trichomes (Type A-E) were identified from pods and calyx of the 12 pigeonpea genotypes under a simple microscope (40x). Type A trichome have a long tubular neck. It is longer than all other trichomes except Type D. Type B is globular. Type C trichomes are unsegmented and nonglobular. Type D is similar to Type A except for the base. The base is absent in Type D trichomes. Type E Trichomes are shorter than all other types.

The density of trichome types A-E varied significantly among the genotypes. In the calyxes Type A, C, D and E trichomes were present in all the genotypes but Type B trichomes were absent in short-duration genotypes such as ICPL 87091, ICPL 87119, and ICPL 88039. Type A and Type D trichomes were present in greater density compared to Type B, C, E. In the flower calyx, highest

Fig 13: Principal component analysis of 12 pigeonpea genotypes based on biological effects of leaf and pod powder impregnated into artificial diet

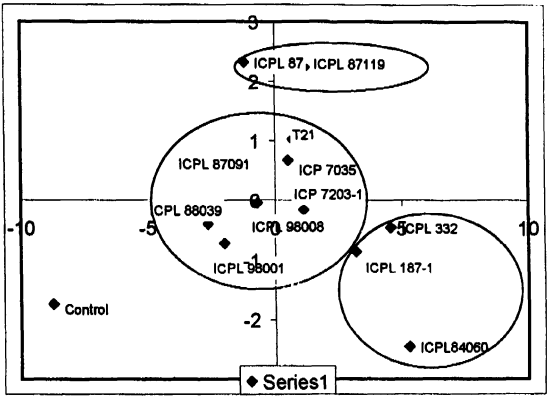


Table 28: Growth of neonate larvae of *H. armigera* on inflorescences of 12 pigeonpea genotypes under Laboratory conditions (2001-2002)

Genotypes	Larval wt 1DAI (g)	Larval wt 5DAI (g)	Larval mortality (%)	Weight gain (%)
ICPL187-1	3.80	5.10	26.67^{abc}	1260^{a}
ICP7035	2.22	27.60	50.00^{ab}	13314^{a}
ICP7203-1	4.33	5.60	23.33^{ab}	1265^{a}
ICPL84060	2.40	3.00	20.00^{ab}	1989^{a}
ICPL87091	3.82	6.40	13.33^{a}	1565^{a}
ICPL87119	4.52	4.20	43.33^{bc}	1045^{a}
ICPL88039	3.25	4.20	40.00^{bc}	1186^{a}
ICPL98001	3.52	4.30	40.00^{bc}	1350^{a}
ICPL98008	1.86	5.90	33.33^{abc}	3837^{a}
T21	3.45	5.00	30.00^{abc}	1589^{a}
Controls				
ICPL87(S)	1.86	5.80	33.33^{abc}	3453^{a}
ICPL332®	5.80	8.20	56.67^{d}	2050^{a}
Mean	3.40	7.10	34.20	2823
FPROB	0.377	0.367	0.075	0.187
LSD	3.20	17.9	25.89	0.024
CV %	56.90	148.8	45	170.1

DAI: Days after initiation. Figures followed by same letter in a column do not differ significantly at P 0.05.
R: Resistant and S: Susceptible.
Weight gain = (Final weight - Initial weight) / Initial weight*100

number of Type A trichomes were present on ICPL 88039 (171.67) and lowest on T 21 (6.67). Type B trichomes were highest on long-duration genotypes such as ICPL 87119 (33.33) and lowest on ICP 7035 (18.33). Type C trichomes are highest in ICPL 87119 (61.61), Type D in ICP 7035 (66.33) and Type E in ICPL 84060 (2.33). Type C trichomes were highest on ICPL 98008 (75.00) and lowest on ICPL 87091 (7.50). Type D trichomes were highest on ICPL 98008 (96.67) and lowest on ICPL 332 (3.33) and absent in ICPL 98001 and ICPL 87119 (Table 29). Greater number of Type E trichomes were present on ICP 7203-1 (2.67), ICPL 84060 (2.33). Among short duration genotypes Type A trichomes are higher in ICPL 88039 (171.67) and Type B trichomes in ICPL 87091 (13.33).

On the pods, Type A-E trichomes were present on all genotypes. There were significant differences in the trichome density among the genotypes tested. Type D trichomes were present in greater density compared to Type A. Type A trichomes were highest on ICP 7035 (118.33) and lowest on ICPL 84060 (7.33). Type B trichomes were higest on T 21 (33.33). Type C were greater on T 21 (145.00). Type D were greater on ICP 7035 (126.67). Type E trichomes did not differ significantly among the genotypes examined (Table 30).

4.2.4 Biochemical analysis

4.2.4.1 Estimation of nitrogen, phosphorus and potassium

Nitrogen, phosphorus, and potassium contents in flowers differed significantly (Table 31). Lowest nitrogen content (1.98%) was observed in flowers of T 21 while highest nitrogen content was observed in flowers of ICPL 332 (2.65%). Among the flowers of long duration genotypes ICPL 87119 had lowest phosphorus content (0.23) while highest phosphorus content was observed in ICPL

Table 29: Mean density of five different types of trichomes on upper and lower interveinal surface of flowers of 12 pigeonpea genotypes (2001-2002)

Genotype	A	B	C	D	E
ICPL 187-1	23.33^{d}	0.00^{f}	11.67^{g}	36.67^{d}	1.33^{ab}
ICP 7203-1	51.67^{b}	10.67^{d}	10.67^{h}	61.67^{c}	2.67^{a}
ICPL 88039	171.67^{a}	0.00^{f}	0.00^{h}	81.67^{ab}	1.00^{a}
ICPL 98001	25.00^{d}	0.00^{f}	33.33^{e}	0.00^{f}	0.33^{c}
ICPL 98008	23.33^{d}	0.00^{f}	75.00^{a}	96.67^{a}	0.00^{c}
ICPL 87091	43.33^{c}	13.33^{c}	7.50^{b}	43.33^{d}	0.67^{b}
T 21	6.67^{g}	15.00^{c}	23.00^{f}	38.33^{d}	1.00^{ab}
ICPL 84060	21.67^{a}	6.67^{e}	46.67^{d}	61.67^{c}	2.33^{ab}
ICPL 87119	16.67^{e}	33.33^{a}	61.67^{c}	0.00^{f}	1.00^{a}
ICP 7035	13.33^{e}	18.33^{b}	66.33^{b}	68.33^{bc}	1.33^{ab}
Controls					
ICPL 332 (R)	11.33^{f}	11.33^{d}	53.33^{d}	3.33^{e}	0.333^{c}
ICPL 87 (S)	23.33^{d}	11.33^{d}	53.33^{d}	41.33^{d}	0.667^{b}
F Prob.	<0.001	<0.001	<0.001	<0.001	0.088
LSD at 5%	4.47	2.972	3.851	16.64	1.662
CV(%)	7.4	17.6	4.5	22.2	93.4

Mean followed by same letter in a column do not differ significantly at P 0.05.
R – Resistant check; S- Susceptible check.

Table 30: Mean density of five different types of trichomes on upper and lower interveinal surface of pods of 12 pigeonpea genotypes (2001-2002)

Genotype	TRICHOME TYPES				
	A	B	C	D	E
ICPL 187-1	28.33^{cd}	8.33^{b}	39.00^{bcd}	9.33^{d}	0.00^{a}
ICP 7203-1	22.33^{cd}	28.33^{a}	136.67^{a}	90.00^{ab}	2.33^{a}
ICPL 88039	19.33^{d}	11.67^{b}	63.33^{bc}	19.33^{c}	1.00^{a}
ICPL 98001	10.67^{d}	4.33^{b}	22.33^{cd}	16.67^{d}	1.00^{a}
ICPL 98008	14.33^{d}	4.00^{b}	73.33^{b}	27.67^{c}	1.00^{a}
ICPL 87091	76.67^{b}	0.00^{c}	31.67^{bcd}	59.00^{bcd}	0.00^{a}
T 21	13.33^{de}	33.33^{a}	145.00^{a}	48.33^{bcd}	1.33^{a}
ICPL 84060	7.33^{e}	10.00^{b}	130.00^{a}	68.33^{bc}	2.67^{a}
ICPL 87119	28.33^{cde}	8.33^{b}	20.67^{d}	53.33^{bc}	0.33^{a}
ICP 7035	118.33^{a}	6.33^{b}	15.00^{d}	126.67^{a}	1.00^{a}
Controls					
ICPL 332 (R)	35.00^{cd}	1.33^{b}	55.00^{bcd}	29.67^{c}	0.667^{a}
ICPL 87 (S)	46.67^{c}	6.67^{b}	63.33^{bc}	53.33^{bc}	1.333^{a}
F Prob.	<0.001	<0.001	<0.001	<0.001	0.005
LSD	25.00	12.80	41.27	42.52	1.613
CV%	42.30	74.80	37.00	50.30	90.70

Mean followed by same letters in a column do not differ significantly.
R – Resistant check and S- Susceptible check.

Table 31: Nitrogen, phosphorus, potassium and protein content (%) of flowers of 12 pigeonpea genotypes (2001-2002)

Genotype	Nitrogen	Phosphorus	Potassium	Protein
ICPL 187-1	2.51^{h}	0.29^{d}	1.33^{c}	15.67^{h}
ICP 7203-1	2.19^{c}	0.25^{b}	1.38^{c}	13.71^{c}
ICPL 88039	2.06^{b}	0.30^{e}	1.63^{f}	12.88^{b}
ICPL 98001	2.43^{g}	0.27^{c}	1.54^{d}	15.19^{g}
ICPL 98008	2.43^{g}	0.32^{f}	1.64^{e}	15.18^{g}
ICPL 87091	2.07^{b}	0.29^{d}	1.66^{e}	12.91^{b}
T 21	1.98^{a}	0.27^{c}	1.61^{e}	12.36^{a}
ICPL 84060	2.40^{f}	0.29^{d}	1.64^{e}	14.98^{f}
ICPL 87119	2.36^{e}	0.23^{a}	1.21^{a}	14.77^{e}
ICP 7035	2.60^{j}	0.27^{c}	1.26^{b}	16.23^{i}
Controls				
ICPL 332 (R)	2.65^{j}	0.272^{c}	1.74^{f}	16.56^{j}
ICPL 87 (S)	2.23^{d}	0.28^{d}	1.33^{c}	13.95^{d}
F Prob.	<0.00	<0.01	<0.001	<0.001
LSD at 5%	0.01	0.01	0.01	0.07
CV(%)	0.30	1.80	0.40	0.30

R – Resistant check and S. - Susceptible check.
Mean followed by same letters in a column do not differ significantly.

98008 (0.32%). Among short duration genotypes highest potassium content was observed in ICPL 332 (1.74%) and lowest in ICPL 87119 (1.21%).

The nitrogen, phosphorus and potassium contents in pods of 12 pigeonpea genotypes differed significantly (Table 32). Lowest nitrogen content was observed in ICPL 88039 (2.16%) among highest in ICPL 84060 (2.86%), followed by ICPL 7203-1 (2.67%). Lowest phosphorus content was observed in T 21 (0.26%) and highest in ICPL187-1 (0.35%). Potassium content was highest in the resistant check ICPL88039 (1.57%) followed by ICPL 98001 (1.54%) and lowest in ICPL 98008 (1.13%).

4.2.4.2 Protein content

The protein content in flowers and pods of the pigeonpea genotypes tested differed significantly (Table 31). The protein content of flowers was more compared to that of pods. Highest protein content was observed in the flowers of ICP 332 (16.56%) and lowest in T 21 (12.36%). Highest protein content was observed in pods of ICPL 84060 (17.85%), among long duration genotypes and ICPL 7203-1 (16.65%) among short duration genotypes. Lowest protein content was observed in pods of ICPL 88039 (13.51%), followed by ICPL 98008 (13.78%). Because of the greater protein content in flowers of ICPL 7035, more damage was observed in flowers of this genotype by *H. armigera* (Table 32).

4.2.4.3 Reducing sugars

Sugar content of leaves and pods of pigeonpea genotypes differed significantly. The sugar content in pods was greater than in the leaves (Table 33). Highest sugar content was observed in leaves of ICPL 187-1 (9.57%), followed by

Table 32: Nitrogen, phosphorus, potassium and protein content (%) of pods of 12 pigeonpea genotypes (2001-2002)

Genotype	Nitrogen	Phosphorus	Potassium	Protein
ICPL 187-1	2.44[e]	0.35[f]	1.46[f]	15.25[d]
ICP 7203-1	2.67[h]	0.26[a]	1.26[c]	16.65[f]
ICPL 88039	2.16[a]	0.25[a]	1.57h	13.51[a]
ICPL 98001	2.57[g]	0.30[d]	1.54[g]	16.07[g]
ICPL 98008	2.21[b]	0.32[e]	1.13[a]	13.78[b]
ICPL 87091	2.21[b]	0.28[c]	1.54[g]	13.78[b]
T 21	2.50[f]	0.26[a]	1.31[d]	15.60[e]
ICPL 84060	2.86[I]	0.32[e]	1.47[f]	17.85h
ICPL 87119	2.34[d]	0.29[c]	1.43[e]	14.64[f]
ICP 7035	2.33[c]	0.27[b]	1.46[f]	14.55[c]
Controls				
ICPL 332 (R.)	2.33[c]	0.29[c]	1.23[b]	14.55[c]
ICPL 87 (S.)	2.33[c]	0.30[d]	1.27[c]	14.54[c]
F Prob.	<0.001	<0,001	<0.001	<0.001
LSD at 5%	0.012	0.0094	0.0108	0.0801
CV%	0.60	1.90	0.50	0.30

R – Resistant check and S – Susceptible check.
Mean followed by same letters in a column do not differ significantly at P 0.05.

Table 33: Percentage of sugars in leaves and pods of 12 pigeonpea genotypes (2001-2002)

Genotype	Leaf (%)	Pod (%)
ICPL 187-1	9.57^{k}	10.70^{k}
ICP 7203-1	9.40^{i}	10.50^{j}
ICPL 88039	9.40^{h}	10.40^{h}
ICPL 98001	8.28^{g}	9.48^{c}
ICPL 98008	9.47^{j}	10.50^{l}
ICPL 87091	5.40^{b}	9.60^{a}
T 21	7.80^{f}	7.80^{a}
ICPL 84060	3.66^{a}	9.40^{b}
ICPL 87119	6.80^{e}	9.70^{f}
ICP 7035	5.4b^{c}	9.60^{e}
Controls		
ICPL 332(R)	9.40^{h}	10.30^{g}
ICPL 87 (S)	5.76^{b}	9.60^{d}
F Prob.	<0.001	<0.001
LSD	0.0431	0.0431
CV(%)	0.30	0.30

Mean followed by same letters in a column do not differ significantly at p 0.05.

ICPL 98008 (9.47%) among short duration genotypes. Lowest sugar content was observed in leaves of ICPL 84060 (3.66%) and higher in ICPL 332 (9.40%). In case of pods, sugar content was greater in ICPL 187-1 (10.70%) and lowest in T 21 (7.80) among short duration genotypes. Among long duration genotypes highest sugar content was observed in ICPL 87119 (9.70).

The principal component analysis of 12 pigeonpea genotypes based on biochemical characters (nitrogen, phosphorus and potassium contents in the plant, per cent of sugars and pod damage) revealed that ICPL 332, ICPL 87091, ICPL 87, ICP 7035, ICPL 88039 are resistant genotypes; ICPL 87119 and T 21 are susceptible genotypes ICPL 98001, ICP 7203-1, ICPL 187-1 and ICPL 84060 are moderately resistant genotypes (Fig.14).

4.2.5 Bioassay of pod surface extracts from ICPL 87 (susceptible check) and ICPL 332 (resistant check) using glass fiber discs

The pod surface extracts of ICPL 87 and ICPL 332 stimulated the feeding by the 3rd, 4th, and 5th instars of *H. armigera*, when presented at pod surface equivalents. When the bioassay was conducted using 3rd instar larvae the antifeedant activity was highest (0.43) in ICPL 332 treated disc (glass fibre disc containing ICPL 332 pod extract extracted in hexane) (Table 34). But highest antifeedant activity was observed in ICPL 87 (0.22) treated disc (glass fibre disc containing ICPL 87 pod extract extracted in methane). When the bioassay was conducted using 4th instar larvae the antifeedant activity was highest in ICPL 332 (-0.18) treated disc (glass fibre disc containing ICPL 332 pod extract extracted in hexane). For 5th instar also highest antifeedant activity was observed on ICPL 332 (2.25) treated disc (glass fibre disc containing ICPL 332 pod extract extracted in

Fig14: Principal component analysis of 12 pigeonpea genotypes based on biochemical characters and pod damage

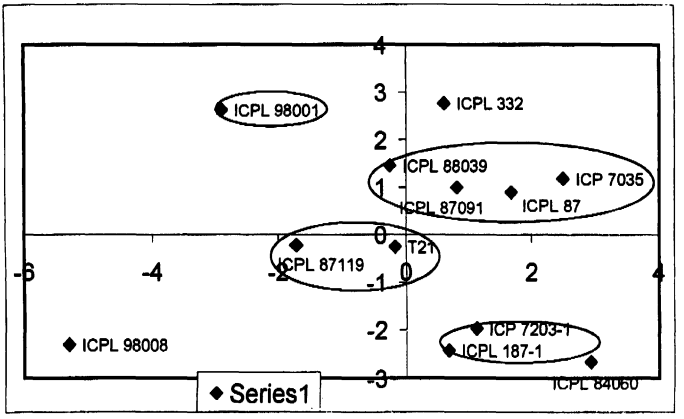


Table 34: Bioassay of pod surface extracts using glass fibre discs and estimation of antifeedant activity of *H. armigera* using 3rd, 4th and 5th instar larvae under laboratory conditions (2000-2001)

3rd instar				4th instar				5th instar			
Genotype	aa (Hex)	aa (Meth)		Genotype	aa (Hex)	aa (Meth)		Genotype	aa (Hex)	aa (Meth)	
ICPW 83	0.12	0.12	0.12	ICPW 83	-2.47	0.33	-1.07	ICPW 83	0.62	-0.13	0.24
ICPL 87	0.157	0.22	0.19	ICPL 87	-1.10	1.93	0.41	ICPL 87	-570.59	3.29	-283.65
ICPL 332	0.43	-0.09	0.17	ICPL 332	-0.18	-0.37	-0.27	ICPL 332	2.25	1.05	1.65
Acc.treat	0.24	0.09		Acc.trea	-1.25	0.63		Acc.trea	-189.24	1.40	
F Prob.				F Prob.				F Prob.			
Var	0.92			Var	0.82			Var	0.18		
Treat	0.25			Treat	0.33			Treat	0.97		
V*T	0.14			V*T	0.74			V*T	0.19		
SEM	0.16			SEM	2.32			SEM	20.98		
SED	0.23			SED	3.28			SED	29.67		
LSD	0.45			LSD	6.61			LSD	59.76		
CV%	313.90			CV%	2378.30			CV%	298.10		

aa - antifeedant activity.

hexane). The amount of leaf discs consumed was greater for ICPL 87 (susceptible check) compared to that of the ICPL 332 (resistant check). Significantly more discs treated with hexane and methanol were consumed compared with the respective controls. The methanol extract was most stimulatory, followed by the hexane extract. The attraction of *H. armigera* adults to ICPL 87 and ICPL 332 extracts indicates that chemical cues are involved in host plant selected by *H. armigera*.

When the bioassay was conducted using 3rd instar larvae the feeding index was highest (13.33) in ICPL 332 treated disc (glass fibre disc containing ICPL 332 pod extract extracted in hexane) (Table 35). Lowest feeding index was recorded (-15.89) in ICPL 87 treated disc (glass fibre disc containing ICPL 87 pod extract extracted in hexane). The feeding index was highest in ICPL 332 (36.61) in ICPL 332 treated disc (glass fibre disc containing ICPL 332 pod extract extracted in methanol). When the bioassay was conducted using 4th instar larvae the feeding index was highest (38.51) in ICPL 332 treated disc (glass fibre disc containing ICPL 332 pod extract extracted in hexane). For 5th instar also highest feeding index (12.33) was recorded for ICPL 332 (glass fibre disc containing ICPL 332 pod extract extracted in hexane).

4.2.6 Bioassay using plant material

4.2.6.1 Relative feeding preference by the 3rd instar larvae of the *H. armigera* towards leaves of different pigeonpea genotypes

4.2.6.1.1 Feeding preference under no-choice conditions

There were no significant differences in the leaf damage ratings up to 24 hours of observation (Table 36). After 48 hrs, lowest feeding was observed in

Table 35: Bioassay of pod surface extracts using glass fibre discs and estimation of feeding index using 3rd, 4th and 5th instar larvae of *H. armigera* (2001-2002)

3rd Instar			4th Instar			5th Instar		
Genotype	FI (hex)	FI (meth)	Genotype	FI (hex)	FI (meth)	Genotype	FI (hex)	FI (meth)
ICPL 83	- 2.75	- 2.75	ICPL 83	10.00	-30.00	ICPL 83	-16.67	-15.29
ICPL 87	-15.89	-76.67	ICPL 87	-8.22	-33.20	ICPL 87	-64.72	-64.72
ICPL 332	13.33	36.67	ICPL 332	38.51	5.00	ICPL 332	12.33	12.33
F Prob.			F Prob.			F Prob.		
Var	0.01		Var	0.02		Var	0.18	
Treat	0.50		Treat	0.01		Treat	0.97	
V*T	0.17		V*T	0.89		V*T	0.19	
SEM	22.54		SEM	2.54		SEM	20.98	
SED	31.87		SED	31.87		SED	29.67	
LSD	64.27		LSD	64.27		LSD	59.76	
CV%	889.90		CV%	889.90		CV%	298.10	

FI - Feeding Index
hex - hexane
meth - methane

Table 36: Relative feeding preference by the third instar larva of *H. armigera* towards leaves of 12 pigeonpea genotypes under no-choice conditions (2001-2002)

Genotype	Damage Rating	
	24 hr.	48 hr.
ICPL 187-1	0.60[a]	1.90[a]
ICP 7203-1	2.10[a]	3.70[b]
ICPL 88039	0.40[a]	0.70[a]
ICPL 98001	1.80[a]	2.60[a]
ICPL 98008	0.10[a]	0.40[a]
ICPL 87091	2.60[a]	4.10[c]
T 21	0.80[a]	1.00[a]
ICPL 84060	0.20[a]	0.30[a]
ICPL 87119	1.30[a]	4.10[c]
ICP 7035	0.40[a]	0.90[a]
Controls		
ICPL 332 (R)	1.90	3.80
ICPL 87 (S)	1.50	3.30
F Prob.	0.004	0.001
LSD at 5%	1.834	2.74
CV(%)	94.70	72.30

R - Resistant check, S - Susceptible check.
Means followed by same letter do not differ significantly.
Damage rating (1=<10% leaves damage and 9=>80% leaves damage)

leaves of ICPL 84060 (DR = 0.30) followed by ICPL 98008 (0.40). Highest damage rating was observed in leaves of ICPL 87091 and ICPL 87119 (4.10).

4.2.6.1.2 Feeding preference under dual-choice conditions

There were no significant differences among the genotypes tested (Table 37). Greater feeding was observed on leaves of ICPL 87091 (2.17) compared to those of the susceptible check, ICPL 87 (1.33). Lowest feeding was observed on T 21 leaves (0.66) compared to the susceptible check ICPL 87 (1.33). Positive 't' values were recorded for all the genotypes indicating that the larvae preferred to feed on the leaves of the susceptible check ICPL 87.

4.2.6.2 Relative preference by the 3rd instar larvae towards flowers of 12 pigeonpea genotypes

4.2.6.2.1 Feeding preference under no-choice conditions

There were no significant differences in feeding preference by the 3rd instar larvae towards the flowers of different pigeonpea genotypes (Table 38). However, highest feeding was recorded in flowers of ICP 7203-1 (DR = 7.40) followed by ICPL 87091 (7.00) among short-duration genotypes and lowest in case of ICPL 187-1 (4.20). Among the long-duration genotypes lowest feeding was observed on flowers of ICPL 84060 (4.10) and ICPL 87119 (7.00).

4.2.6.2.2 Feeding preference under dual-choice conditions

Greater feeding was observed on flowers of ICP 7035 (DR = 7.17) in comparison to the susceptible check, ICPL 87 (6.83). Negative 't' values were recorded for ICP 7035 indicating more damage rating in ICP 7035 compared to the

Table 37: Relative feeding preference by the third instar larvae of *H. armigera* towards leaves of 12 pigeonpea genotypes under dual- choice conditions (2001-2002)

Genotype	Damage rating*		t value
	Test genotype	ICPL 87	
ICPL 187-1	1.00	1.50	2.00
ICP 7203-1	1.88	1.66	1.00
ICPL 87091	2.17	1.33	1.00
ICPL 88039	1.80	1.33	1.00
ICPL 98001	0.83	1.17	1.00
ICPL 98008	1.33	1.50	2.33
T 21	0.66	1.33	1.00
ICPL 84060	0.80	1.66	4.00
ICPL 87119	1.00	1.67	1.33
ICP 7035	1.50	1.66	9.00
ICPL 332 (R)	0.66	1.50	9.00

*Damage rating 1=<10% of leaves damaged 9=>80% leaves damaged.

Table 38: Relative feeding preference by the third instar larva of *H. armigera* towards flowers of 12 pigeonpea genotypes under no-choice conditions (2001-2002)

Genotype	DR (24 h)
ICPL 187-1	4.20[b]
ICP 7203-1	7.40[cd]
ICPL 88039	6.00[bcd]
ICPL 98001	5.60[bc]
ICPL 98008	4.60[b]
ICPL 87091	7.00[cd]
T 21	5.50[a]
ICPL 84060	4.10[a]
ICPL 87119	7.00[cd]
ICP 7035	6.80[cd]
Controls	
ICPL 332 (R)	5.60[bc]
ICPL 87 (S)	5.00[b]
F prob.	35.00
LSD at 5%	2.40
CV(%)	35.00

R - Resistant check, S - Susceptible check.
Mean followed by same letter do not differ significantly.
DR= Damage Rating

susceptible check ICPL 87. In all the other genotypes tested positive 't' values were recorded indicating more preference for the flowers of ICPL 87 as compared to test genotype (Table 39).

4.2.6.2.3 Feeding preference under multi- choice conditions

In case of short-duration genotypes greater feeding was observed (Table 40) in flowers of ICP 7203-1 (DR=7.40) followed by those of ICPL 87091 (7) and ICPL 87119 (7.00). Lowest feeding was observed in T 21 (0.80). In case of long-duration genotypes lowest feeding was observed in ICPL 84060 (4.10).

4.2.6.3 Relative preference by the 3rd instar *H. armigera* larvae towards pods of 12 pigeonpea genotypes

4.2.6.3.1 Multi-choice conditions

Lowest damage rating after 48 hrs was observed in pods of T 21 (1.25), followed by ICP 7203-1 (1.40), while highest pod damage was observed in pods of ICPL 87091 (7.40) after 48 h (Table 41). In case of long duration genotypes, there were no significant differences in larval feeding on pods. Highest damage rating was observed in pods of the susceptible check, ICPL 87 (7.50) followed by ICP 7035 (1.80) (Table 42).

4.2.6.3.2 Effect of extracting the pod surface chemicals by different solvents on feeding preference by the *H. armigera* larvae

There was greater feeding on pods extracted with hexane than on the pods extracted in methanol and distilled water. In case of susceptible check, ICPL 87 there were no differences in the feeding in case of control pods, and the pods

Table 39: Relative feeding preference by the third instar larva of *H. armigera* towards flowers of 12 pigeonpea genotypes under dual-choice condition (2001-2002)

Genotype	Damage rating		t-value
	Test genotype	Control (ICPL 87) (S)	
ICPL 187-1	2.17	6.50	3.00
ICP 7203-1	3.83	7.17	1.63
ICPL 87091	8.67	3.67	1.96
ICPL 88039	5.83	7.17	1.17
ICPL 98001	4.16	4.33	5.29
ICPL 98008	3.88	6.00	4.65
T 21	3.50	5.50	1.75
ICPL 84060	1.83	6.50	5.25
ICPL 87119	4.00	5.00	3.77
ICP 7035	7.17	6.83	-1.19
ICPL 332	6.00	6.66	1.76

R - Resistant check, S - Susceptible check.
* Damage rating (1=<10% flowers damaged and 9 = >80% flowers damaged)

Table 40: Relative feeding preference by the third instar larva of *H. armigera* towards flowers of 12 pigeonpea genotypes under multi-choice conditions (2001-2002)

Genotype	DR (24 h)
ICPL 187-1	4.20[a]
ICP 7203-1	7.40[a]
ICPL 88039	6.00[a]
ICPL 98001	5.60[a]
ICPL 98008	4.60[a]
ICPL 87091	7.00[a]
T 21	0.80[a]
ICPL 84060	4.10[a]
ICPL 87119	7.00[a]
ICP 7035	6.80[a]
Controls	
ICPL 332 (R)	5.60[a]
ICPL 87 (S)	5.00[a]
Fprob	3.50
LSD at 5%	1.27
CV(%)	3.407

R - Resistant check, S - Susceptible check.
Means followed by same letter do not differ significantly.
* Damage rating (1=<10% flowers damaged and 9=>80% flowers damage)

Table 41: Relative feeding preference by the third instar larva to *H. armigera* towards pods of eight pigeonpea genotypes under multi-choice condition (2001-2002)

Genotype	DR (24 h.)	DR (48 h.)
ICPL 187-1	1.80[a]	4.40[a]
ICP 7203-1	0.90[a]	1.40[a]
ICPL 88039	1.70[a]	2.60[ab]
ICPL 98001	2.30[a]	3.50[a]
ICPL 87091	2.50[a]	7.40[ab]
ICPL 98008	0.40[a]	1.40[a]
T 21	0.75[a]	1.25[a]
Controls		
ICPL 332 (R)	0.80[a]	1.50[a]
ICPL 87 (S)	1.70[a]	4.70[a]
Mean		
F Prob.	0.558	0.605
LSD at 5%	4.78	4.72
CV(%)	145.20	127.70

R - Resistant check, S - Susceptible check.
Means followed by same letter do not differ significantly.
Damage rating (1=<10% pods damage and 9=>80% pods damage)

Table 42: Relative feeding preference by the third instar larva to *H. armigera* towards pods of four pigeonpea genotypes under multi-choice condition (2001-2002)

Genotype	DR (24)	DR (48)
ICPL 84060	0.80[a]	1.30[a]
ICPL 87119	1.20[a]	1.70[a]
ICP 7035	1.40[a]	1.80[a]
Controls		
ICPL 332 (R)	0.30[a]	1.00[a]
ICPL–87 (S)	0.75[a]	7.50[b]
Mean		
F Prob.	0.284	0.05
LSD at 5%	5.78	5.78
CV%	93.70	89.40

R - Resistant check, S - Susceptible Check
Means followed by same letter do not differ significantly.
Damage rating (1=<10% pods damage and 9=>80% pods damage)

extracted in distilled water and methanol. In case of ICPL 84060, ICPL 87119 and ICP 7035 greater feeding was recorded in pods extracted in hexane compared to pods extracted in methanol. The results suggested that the compounds extracted in hexane and methanol were important in determining feeding preference by the *H. armigera* larvae.

Under dual-choice conditions, the larvae were offered a choice between a control pod and a pod extracted in hexane or methanol or distilled water. Greater feeding was recorded in pods extracted in hexane as compared to the control pods. When a choice was offered to the larva between a control pod and a pod extracted in hexane negative `t' values were recorded for ICP 7035, ICPL 87, ICPL 98008, ICPL 87091, ICPL 88039, ICPL 98001, ICPL 84060, and ICP 7203-1 suggesting greater feeding in pods extracted with hexane compared to control pods. For ICPL 332, ICPL 187-1, and T 21 the pod damage ratings were less on pods extracted with hexane compared to the control pods (Table 43).

When a choice was offered to 3rd instar larvae between a control pod and pod extracted in methanol, negative `t' values were observed in case of ICPL 187-1, ICPL 87, ICPL 98008, ICPL 87091, ICPL 88039, ICPL 98001 and ICPL 87119 indicating greater damage in pods extracted in methanol than on the control pods. For ICPL 332, ICP 7035, ICPL 84060 and T 21 the damage in control pods was greater when the pods were extracted with methanol (Table 44).

When the larvae were offered a choice between control pods and pods extracted in distilled water, negative `t' values were observed in case of ICPL 87091, T 21 and ICP 7203-1 pods indicating more damage in pods extracted with water compared to the control pods. For the other genotypes, the damage ratings

Table 43: Relative feeding preference by the third instar larvae of *H. armigera* towards pods of 12 pigeonpea genotypes washed with hexane in comparision to unwashed pods in dual-choice test under laboratory conditions (2001-2002)

Genotype	Damage ratings (24 h)			Damage ratings (48 h)		
	Pod extracted with hexane	Un-treated pod	t-value	Pod extracted with hexane	Un-treated pod	t-value
ICPL 187-1	0.50[a]	0.53[a]	0.12	0.95[a]	0.90	0.13
ICP 7203-1	0.63[a]	0.60[a]	0.13	0.93[a]	0.80	-0.52
ICPL 88039	1.13[a]	0.73[a]	-1.44	1.73[a]	1.10	-2.83
ICPL 98001	1.65[a]	1.43[c]	-1.58	2.45[a]	2.05	-2.21
ICPL 98008	1.10[a]		1.75	2.23[a]	1.85	-1.22
ICPL 87091	1.58[a]	0.80[b]	-2.81	2.40[a]	1.79	-2.39
T 21	0.80[a]	0.60[a]	-0.74	0.80[a]	1.08	1.50
ICPL 84060	0.75[a]	0.58[a]	-0.90	1.03[a]	0.73	-0.98
ICPL 87119	0.98[a]	0.95[a]	-0.10	1.03[a]	1.03	0.00
ICP 7035	0.34[a]	0.42[c]	0.47	0.85[a]	0.43	-2.16
Control						
ICPL 332 (R)	0.40	0.85	2.11	0.93[a]	1.55	2.00
ICPL 87 (S)	0.34	0.42	0.47	2.45[a]	1.88[b]	+2.21

R – Resistant check and S – Susceptible check.
Damage rating (1 = <10%, and 9 = >80% of pods are damaged).
Figures followed by same letter in a row do not differ significantly at p 0.05.

Table 44: Relative feeding preference by the third instar larvae of *H. armigera* towards pods of 12 pigeonpea genotypes washed with methanol in comparision to unwashed pods in dual-choice test under laboratory conditions (2001-2002)

Genotype	Damage ratings (24 h)			Damage ratings (48 h)		
	Pod extracted with methanol	Un-treated pod	t- value	Pod extracted with methanol	Un-treated pod	t-value
ICPL 187-1	0.55	0.43	0.66	0.75	0.68	-0.23
ICP 7203-1	0.70	0.63	-0.41	0.83	0.83	0.00
ICPL 88039	1.04	0.73	-1.61	1.50	1.28	-1.41
ICPL 98001	1.28	0.73	-2.77	2.00	1.45	-2.37
ICPL 98008	1.48	1.05	-2.00	2.23	2.00	-1.69
ICPL 87091	1.40	0.80	-1.95	2.28	1.98	-0.93
T 21	0.65	0.93	1.50	0.90	1.13	1.11
ICPL 84060	0.50	0.50	0.00	0.60	0.75	0.83
ICPL 87119	0.88	0.63	-1.20	1.08	0.93	-0.63
ICP 7035	0.50	0.63	0.52	0.53	0.85	1.20
Controls						
ICPL 332 (R)	0.55	0.62	0.20	0.53	0.85	1.20
ICPL 87 (S)	0.55	0.62	0.2	2.00	1.45	-2.37

R – Resistant check and S – Susceptible check.
Damage rating (1 = <10%, and 9 = >80% of pods are damaged).
Figures followed by same letter in a row do not differ significantly at p 0.05.

were more in control pods as compared to the pods extracted in distilled water (Table 45)

4.3 TOLERANCE

Tolerance to *H armigera* damage was studied in pigeonpea genotypes under protected and unprotected conditions in the field

4.3.1 Pod damage ratings

Under protected conditions, the differences in pod damage ratings among the genotypes were not significant (Table 46) However under protected condition, the differences were significant among the genotypes tested In case of long- duration genotypes, lowest pod damage ratings was observed in ICPL 332 (3 33) followed by ICPL 84060 (5 00) while in the short duration genotypes lowest pod damage rating was observed in ICPL 98001 (6 00), followed by ICPL 88039 (8 00) and ICPL 87 (8.33)

4.3.2 Pod borer damage

Under protected conditions, there were no significant differences in per cent pod damage (Table 46). However, under unprotected conditions lowest pod damage was recorded in ICPL 332 (22 90%), followed by ICP 7035 (24 40%), ICPL 98001 (57 90%), and ICPL 7203-1 (64 90%). The susceptible checks ICPL87 and ICPL 87119 suffered a pod damage of 83 2% and 67% respectively

4.3.3 Seed weight per 100 grains

Mean seed weight per 100 grains was significantly greater under protected conditions compared to the unprotected conditions (Table 47) Among the

Table 45: Relative feeding preference by the third instar larvae of *H. armigera* towards pods of 12 pigeonpea genotypes washed with water in comparision to unwashed pods in dual-choice test under laboratory conditions (2001-2002)

Genotype	Damage ratings (24 h)			Damage ratings (48 h)		
	Pod extracted with water	Un-treated pod	t-value	Pod extracted with water	Un-treated pod	t-value
ICPL 187-1	0.50	0.28	-1.44	0.83	0.70	0.37
ICP 7203-1	0.75	0.73	-1.09	0.90	0.85	-0.21
ICPL 88039	1.025	1.03	0.00	1.23	1.50	1.12
ICPL 98001	1.18	1.13	0.21	1.78	2.95	1.18
ICPL 98008	1.58	1.20	-1.22	2.23	1.70	1.32
ICPL 87091	1.90	1.03	-4.40	2.50	2.35	-0.63
T 21	0.65	0.48	0.014	1.13	0.95	-0.86
ICPL 84060	0.5	0.63	0.84	0.70	0.73	0.11
ICPL 87119	0.75	0.90	0.79	0.95	0.98	0.11
ICP 7035	3.00	0.63	-0.96	0.50	1.75	2.88
Controls						
ICPL 332 (R)	0.48	0.73	1.35	0.55	1.43	3.81
ICPL 87 (S)	1.18	1.30	0.53	1.78	2.95	1.18

R – Resistant check and S – Susceptible check.
Damage rating (1 = <10%, and 9 = >80% of pods are damaged).
Figures followed by same letter in a row do not differ significantly at p 0.05.

Table 46: Damage caused by *H. armigera* in 12 pigeonpea genotypes under protected and unprotected conditions (2001-2002)

Genotype	Damage Ratings			Pod damage (%)					
				Actual			Angular		
	Protected	Unprotected	Mean	Protected	Unprotected	Mean	Protected	Unprotected	Mean
ICPL 187-1	1.00	8.00	4.50	8.50	79.60	44.10	16.97	63.15	40.06
ICP7203-1	1.67	6.67	4.17	9.30	64.90	37.10	17.56	55.02	36.29
ICPL88039	1.32	8.00	4.67	10.50	78.00	44.20	18.82	18.82	40.64
ICPL 98001	2.00	6.00	4.00	12.40	57.90	35.10	20.58	20.58	35.08
ICPL 98008	1.33	8.67	5.00	11.60	82.50	47.00	19.78	19.78	42.62
ICPL87091	1.00	7.33	4.17	9.40	71.60	40.50	17.84	17.84	38.08
T21	1.33	7.67	4.50	11.30	78.90	45.10	19.39	19.39	41.02
ICPL 84060	1.33	5.00	3.17	9.80	39.90	24.90	18.15	18.15	28.54
ICPL87119	2.33	7.33	4.83	14.80	67.00	40.90	22.42	22.42	38.86
ICP 7035	2.33	3.67	3.00	18.50	24.40	21.40	25.22	29.51	27.36
Controls									
ICPL 332 (R)	1.00	3.33	1.58	9.80	22.90	16.30	18.22	18.22	23.36
ICPL 87 (S)	2.33	8.33	6.67	13.90	83.20	48.60	21.79	21.79	43.93
Mean	1.58	6.67		11.60	62.60	37.10			
	Fprob	LSD		Fprob	LSD		Fprob	LSD	
Treat	<0.001	0.414		0.001	7.02		0.001	4.59	
Geno	0.001	1.403		<0.001	13.48		<0,001	8.692	
Treat*geno	<0.001	1.909		<0.001	18.53		<0,001	11.95	
CV%	29.2			31.2			20.6		

R-Resistant check and S- Susceptible check.
Means followed by same letters in a column do not differ significantly at P 0.05.

Table 47: Yield components of 12 pigeonpea genotypes under protected and unprotected conditions (2001-2002)

Genotype	100-seed weight(g)			Total pods/plant			Yield plant^{-1}(g)		
	Protected	Unprotected	Mean	Protected	Unprotected	Mean	Protected	Unprotected	Mean
ICPL 187-1	8.09	7.87	7.98	107.77	13.73	119.33	28.77	21.23	25.00
ICP7203-1	9.85	8.94	9.39	238.10	80.33	159.23	58.23	45.67	51.93
ICPL88039	8.94	8.52	8.73	57.90	48.77	53.33	28.40	32.60	24.97
ICPL 98001	7.78	7.99	7.89	77.00	83.00	80.00	20.43	47.17	33.80
ICPL 98008	8.21	7.80	8.01	63.23	85.90	74.57	14.43	48.40	31.43
ICPL87091	9.69	9.91	9.35	41.10	44.77	30.77	20.57	13.70	17.13
T21	8.16	7.54	7.85	144.60	75.33	74.57	37.23	38.27	37.77
ICPL 84060	8.89	7.88	8.38	120.10	132.23	126.17	29.57	53.57	36.57
ICPL87119	11.44	10.70	11.10	133.77	134.33	89.27	35.10	48.43	41.80
ICP 7035	11.43	10.10	10.76	41.57	28.33	34.93	42.10	33.60	37.87
Controls									
ICPL 332 (R)	7.04	6.85	6.95	235.77	129.33	182.40	40.77	48.53	43.17
ICPL 87 (S)	9.6	7.17	8.38	72.10	131.33	101.73	24.90	17.27	21.07
Mean	9.096	8.368	8.73	111.10	82.53	96.83	36.33	30.80	33.53
	Fprob	LSD		Fprob	LSD		Fprob	LSD	
Treat	0.008	0.276		0.049	28.15		0.046	5.33	
Geno	<0.001	0.856		<0,001	28.24		<0.001	13.66	
TREAT*GENO	0.278	1.165		<0,001	40.50		0.017	18.67	
CV%	8.4			25.1			35.4		

R - Resistant check, S- Susceptible check.
Means followed by same letters in a column do not differ significantly at P 0.05.

long duration genotypes higher 100-seed weight was recorded for ICPL 87119 (11.44 g) under protected conditions and 10.70 g under unprotected conditions. In case of ICPL 87119 and ICPL 7035 (because of compensation) significantly high seed weight per 100 grains was recorded under unprotected conditions. In case of short-duration genotypes higher 100-seed weight was recorded for ICPL 87091(9.69 g under protected and 9.91 g under unprotected conditions).

4.3.4 Grain yield

Significantly high grain yield per hectare was recorded under protected conditions as compared to unprotected conditions (Table 48). Highest grain yield per hectare was obtained in ICP 7203-1 (7408 kg) followed by ICPL 187-1 (4495 kg) among short-duration genotypes and ICPL 332 (5551 kg), followed by ICPL 87119 (5257 kg) in case of long-duration genotypes under protected conditions. Under unprotected conditions among long-duration genotypes highest grain yield was obtained in ICPL 332 (4361 kg), followed by ICPL 187-1 (3188 kg), ICPL 84060 (3126 kg). In case of short-duration genotypes highest grain yield was obtained in ICPL 187-1 (3188 kg).

4.3.5 Loss in grain yield (%)

Tolerance index based on loss in the grain yield indicated that ICPL 332 (0.21), and ICPL 84060 (0.24), were the most tolerant genotypes followed by ICPL 87 (0.29), ICPL 87119 (0.51), T 21 (0.64) and ICPL 88039 (0.69). Highest grain yield reduction i.e., avoidable loss was recorded on ICPL 187-1 (36.46 %) followed by T 21 (34.06%), ICPL 98008 (34.80%) and ICPL 88039 (34.23%) (Table 48).

Table 48: Loss in yield due to *H. armigera* damage in 12 pigeonpea genotypes under protected and unprotected conditions (2001-2002)

Genotype	Yield (kg/ha)		Corrected yield (expected)				Loss in weight		
	Actual in Protected	Expected in Protected	Unprotected	Protected	Unprotected	Mean	Protected	Unprotected	Avoidable loss
ICPL 187-1	4495	4880	3188	2.93	3.44	3.18	7.86	44.32	36.46
ICP7203-1	7408	8081	1801	4.85	1.88	3.36	8.43	36.48	28.05
ICPL88039	1745	1920	536	1.15	0.57	0.86	9.45	43.68	34.23
ICPL 98001	2168	2425	2425	1.46	0.37	0.91	11.03	36.43	25.40
ICPL 98008	1908	1101	986	0.66	1.11	0.88	10.34	45.14	34.80
ICPL87091	394	431	52	0.26	0.06	0.16	8.59	41.45	32.86
T21	4958	5463	1804	3.28	1.92	2.60	10.02	44.08	34.06
ICPL 84060	4089	4495	3126	2.70	2.66	2.68	8.91	27.42	18.51
ICPL87119	5257	5986	2600	3.59	2.70	3.15	12.78	39.79	27.01
ICP 7035	2637	3075	158	1.85	1.12	0.98	15.41	19.52	4.11
Controls									
ICPL 332 (Res.)	5551	6098	4361	3.66	3.22	3.44	8.92	18.05	33.19
ICPL 87 (Sus.)	3257	3710	418	2.23	0.47	1.35	12.17	45.36	9.134
Mean	3599	3971	2599	2.38	1.54	1.96	10.33	36.85	26.52
	Fprob	LSD		Fprob	LSD		Fprob	LSD	
Treat	0.012	946.7		0.046	0.8066		<0.001	3.277	
Geno	<0.001	1122.8		<0.001	0.9032		<0.001	6.14	
TREAT*GENO	<0.001	1582.9		0.02	1.3172		<0.001	8.44	
CV%	37.1			40.8			22.4		

Res. - Resistant check, Sus. - Susceptible check.
Means followed by same letters do not differ significantly.

4.3.6 Eggs and larvae

In the unsprayed field among the long duration genotypes lowest number of eggs were recorded on ICPL 87119 (4.28) followed by ICPL 84060 (4.52). Among the short duration genotypes, lowest number of eggs were recorded on ICPL 187-1 (4.27). Total number of larvae were more on ICP 7035 (4.46) and less on ICPL 332 (4.21) followed by ICPL 84060 (4.37) among the long duration genotypes. Among the short duration genotypes lowest number of larvae were recorded on ICPL 98001 (4.04) (Table 49). The total number of eggs and larvae were more during unsprayed condition and less under sprayed conditions (Table 50). In the sprayed field lowest number of eggs were recorded in the ICPL 84060 (0.59) followed by resistant check ICPL 332 (1.15) among the long duration genotypes. In case of short duration genotypes lowest number of eggs were recorded in ICPL 98008 (0.88). The total number of larvae were less in ICP 7035 (0.23) followed by ICPL 332 (0.14) in case of long duration genotypes. In case of short duration genotypes lowest number of larvae were recorded in ICPL 98008 (0.12) (Table 50).

4.3.7 Correlation between pod borer damage and yield in pigeonpea genotypes

There was a positive and significant correlation between pod damage rating and pod damage per cent (0.85). There was a negative correlation between grain yield and pod damage rating (-0.62). This indicates that as the pod damage rating increases the yield decreases (Table 51). Principal component analysis of number of eggs, larvae, pod damage rating, damage per cent and yield indicated that ICPL 87, ICPL 87091, ICPL 98001, T 21, ICPL 187-1 are resistant genotypes; ICPL 98008, ICPL 87119 are susceptible genotypes; ICPL 332, ICP 7035, ICPL 88039, ICP 7203-1, ICPL 84060 are moderately resistant genotypes (Fig.15).

Table 49: Population of *H. armigera* on 12 pigeonpea genotypes under un-protected conditions (2001-2002)

Genotype	No. of flowers	Eggs inflorescence^{-1}					Total eggs	Larvae inflorescene^{-1}					Total larvae
		5th day	7th day	9th day	20th day	30th day		5th day	7th day	9th day	20th day	30th day	
ICPL 187	86	0.95	0.79	0.87	0.75	0.91	4.27	0.95	0.75	0.86	0.91	0.91	4.28
ICP 7203-1	97	1.05	0.84	0.91	0.71	0.95	4.45	1.17	0.75	1.07	0.87	1.02	4.87
ICPL 88039	64	1.05	0.87	0.79	0.79	0.84	4.34	0.94	0.83	0.79	0.84	0.87	4.27
ICPL 98001	64	1.05	0.79	0.86	0.71	0.87	4.29	0.83	0.79	0.71	0.79	0.91	4.04
ICPL 98008	67	1.12	0.79	0.79	0.71	0.87	4.29	0.95	0.75	1.11	0.95	1.05	4.80
ICPL 87091	70	1.13	1.22	1.11	0.98	1.10	5.54	0.98	0.79	0.98	0.98	1.01	4.75
T 21	73	1.02	0.84	0.75	0.71	0.98	4.29	0.86	0.83	0.90	0.98	0.94	4.51
ICPL 84060	101	1.40	0.79	0.71	0.71	0.91	4.52	0.91	0.71	0.79	0.98	0.94	4.33
ICPL 87119	48	0.98	0.71	0.79	0.75	1.05	4.28	0.91	0.75	0.90	0.91	0.91	4.37
ICP 7035	77	1.11	1.00	1.11	0.84	1.14	5.21	0.91	0.87	0.75	0.95	0.98	4.46
Controls													
ICPL 332 (R)	71	1.45	0.75	0.75	0.71	1.12	4.77	0.90	0.71	0.75	0.95	0.91	4.21
ICPL 87 (S)	73	1.20	1.14	1.08	0.98	0.98	5.37	1.05	0.83	1.08	0.98	0.95	4.88
Mean	75	1.13	0.88	0.88	0.98	0.98	4.62	0.95	0.95	0.78	0.92	0.95	4.48
F Prob.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

R - Resistant check, S - Susceptible check

Table 50: Population of *H. armigera* on 12 pigeonpea genotypes under protected conditions (2001-2002)

Genotype	No. of flowers	Eggs inflorescence^{-1}					Total eggs	Larvae inflorescene^{-1}					Total larvae
		5th day	7th day	9th day	20th day	30th day		5th day	7th day	9th day	20th day	30th day	
ICPL 187	86	2.25	0.47	0.10	0.00	0.00	1.65	0.57	0.74	0.50	2.00	0.00	0.83
ICP 7203-1	98	0.33	0.63	0.16	0.00	0.00	1.11	0.77	0.63	0.24	0.20	0.10	0.18
ICPL 88039	64	2.81	0.50	0.12	0.00	0.00	1.16	0.48	0.55	0.35	0.30	0.00	0.22
ICPL 98001	72	14.55	0.39	0.14	0.00	0.00	4.97	0.23	1.73	0.25	0.10	0.10	0.15
ICPL 98008	65	2.34	0.25	0.21	0.00	0.00	0.88	0.92	0.60	0.25	0.10	0.00	0.12
ICPL 87091	70	7.80	0.00	1.00	1.00	0.00	3.56	1.43	1.66	0.25	0.20	0.09	0.18
T 21	70	0.96	0.50	0.25	0.00	0.00	1.35	0.50	0.62	0.30	0.40	0.33	0.34
ICPL 84060	102	0.16	0.41	0.00	0.00	0.00	0.59	0.50	0.36	0.00	0.00	0.00	0.00
ICPL 87119	48	3.42	0.43	0.14	0.00	0.00	1.22	0.73	0.65	1.00	0.40	0.03	0.48
ICP 7035	78	5.02	1.31	0.16	0.00	0.00	2.99	1.00	1.33	0.50	0.20	0.00	0.23
Controls													
ICPL 332 (R)	72	1.27	0.54	0.10	0.00	0.00	1.15	0.57	0.57	0.25	0.10	0.07	0.14
ICPL 87 (S)	68	3.65	1.00	0.18	1.00	0.00	4.35	1.48	1.94	1.85	0.50	0.17	0.84
Mean	75	2.09	0.54	0.21	0.17	0.00	2.08	0.77	0.95	0.48	0.38	0.07	0.31
F Prob.	<0.001	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

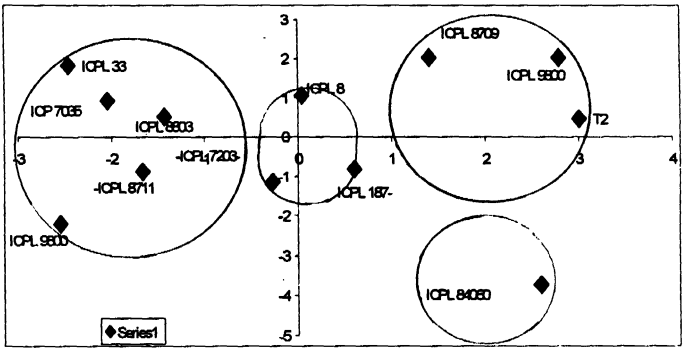
R - Resistant check and S - Susceptible check

Table 51: Correlations between pod borer damage and yield in 12 pigeonpea genotypes (2001-2002)

Sl. No	Yield and damage parameters	Correlation coefficient
1	Damage rating and pod damage percentage	0.85***
2	Total eggs and total larvae	0.32
3	Total eggs and yield	0.35
4	Pod damage percentage and yield	-0.62
5	Yield and damage rating	0.07
6	Larvae and yield	0.07
7	Pod damage percentage and total eggs under laboratory conditions	0.50

* Significantly different at 5% probability.

Fig15: Principal component analysis on number of eggs, larvae, damage rating, damage percentage and yield



Chapter V

DISCUSSION

CHAPTER – V

DISCUSSION

The results obtained in the investigation on Mechanisms of resistance to *Helicoverpa armigera* (Hubner) in pigeonpea [*Cajanus cajan* (L.) Millsp.] are dicussed in this chapter.

5.1 STABILITY OF RESISTANCE TO *H. armigera* IN PIGEONPEA

Among the 12 pigeonpea genotypes tested, the G x E interaction for pod borer damage was significant for some genotypes indicating the non stability of resistance to pod borer over seasons.

Least pod damage was recorded in ICP 187-1 (39%), followed by ICPL 84060 (52%) and ICPL 88039 (47%). These genotypes were stable in their reaction to *H. armigera* over seasons. ICPL 87119 was high yielding, but the pod damage was high, with slope >1 and unit rms value, suggesting that this genotype is more susceptible under climatic conditions favourable to *H. armigera*. In case of ICPL 7203-1, pod damage was low, and grain yield was high, with a unit slope and rms value of 4. This indicated that genotype ICP 7203-1 is unstable in its reaction to pod borer damage. In case of ICPL 98008, less pod damage and high grain yield were observed with a unit slope and minimum rms values which indicated its stability of reaction to *H. armigera* damage.

In case of ICPL 84060 and ICPL 87119, the pod damage rating and slope were significantly less than one, and rms = 0; indicating stable reaction to pod

borer damage. In case of ICPL 187-1, the slope was greater than one with minimum rms values, suggesting unstable reaction to *H. armigera* over seasons.

During the 2000 cropping season, pod borer damage was significantly lower in ICPL 187-1 (21.75%), followed by ICPL 84060 (22.68%) and ICPL 98001 (24.32%), which were on par with the resistant check, ICPL 332 (31.09% pod damage). The highest pod damage was recorded in T 21 (52.29%), while the susceptible check ICPL 87 suffered 52.22% pod damage. In case of ICPL 87091, the damage caused by *H. armigera* to foliage was more compared to the other genotypes tested.

During the 2001-2002 season in second planting, lowest pod borer damage was recorded in ICPL 187-1 (44.8%), which was lower than the damage in the resistant check, ICPL 332 (56.09%). For ICPL 7203-1, ICPL 84060, and ICPL 98008; the pod borer damage was on par with that of the resistant check, ICPL 332. Highest pod borer damage was recorded in ICPL 98001 (89.25%), which was on par with the susceptible check, ICPL 87 (83.50%).

Highest grain yields per plot were recorded in the resistant check, ICP 332 (2.61 kg per plot) during the 2000-2001 cropping season. Grain yields of ICPL 187-1, ICPL 87119 and ICPL 84060 were on par with each other. Significantly low grain yield was recorded in ICPL 87091 (0.031 kg per plot), which was on par with that of the susceptible check, ICPL 87 (0.25 kg per plot). In the second season (2001-2002), the grain yields did not differ significantly but grain yields were numerically greater in ICPL 332 (3.77 kg), ICPL 84060 (3.40 kg), ICPL 87119 (3.23 kg), ICPL 7203-1 (2.28 kg), and ICPL 187-1 (2.26 kg). In the first planting, highest grain yields were obtained in ICPL 332, ICPL 7203-1, ICPL 84060, ICPL 98008 and T 21, and lowest in ICPL 87091, which was on par with the

susceptible check, ICPL 87. During 2001-2002 season significantly higher grain yield was obtained for ICPL 332 (2.56 kg), followed by ICPL 187-1 (1.90 kg), ICPL 84060 (1.78 kg) and ICPL 87119 (1.59 kg) as compared to ICPL 87.

Amongst the short-duration genotypes; ICPL 187-1, ICPL 98008, ICPL 7203-1, T 21 and ICPL 88039 had low pod borer damage and reasonably high grain yields compared to the other genotypes tested. All these genotypes were determinate types. ICPL 87 and ICPL 98001 had high pod damage and low yields. ICPL 87091 exhibited the highest pod borer damage and determinate type of growth habit.

Among the long-duration genotypes, ICPL 84060 and ICPL 87119 were high yielding and were on par with the resistant check, ICPL 332. All these genotypes were of indeterminate growth habit. ICP 7035 was also high yielding, but the pod borer damage in this variety was higher than ICPL 332 and the grain yield was low. ICP 7035 suffered more damage at the flowering stage than at the poding stage. This had indeterminate type of growth habit.

Singh and Choudhary (1980) reported that varieties with bold seed were most suited for growing in favourable environments. Tomer *et al.* (1973) also concluded that large seeded chickpea cultivars were unstable and were only suitable for high-yielding environments. In the present studies, genotypes with bold grain (ICP 7035 and ICPL 87119) were unstable in grain yield and were susceptible to *H. armigera.*

Desai *et al.* (1991) tested 18 pigeonpea genotypes for stability of grain yield. The hybrid MTH 9 performed consistently well under low management

conditions with a highly significant regression coefficient (bi =1.96), while ICPL 227 exhibited stability in its performance over the years. The extent of genotype x environment interaction for grain yield and its components in 29 pigeonpea lines were evaluated in 3 environments by Dahiya and Singh (1993). Six genotypes were stable for grain yield as they exhibited high mean performance, a unit regression coefficient, and a very low magnitude of deviation from regression.

Ten genotypes of short-duration pigeonpea were evaluated for stability by Tyagi and Agarwal (1995). Highly significant mean squares were observed for genotypes, and genotype x environment interaction. ICPL 151 was the most stable genotype, in which the regression coefficient did not deviate from unity and had a non-significant minimum deviation from regression.

In the present studies among the 12 genotypes tested, the grain yields of ICPL 84060, ICPL 87119, ICPL 187-1, and ICPL 98001 were on par with the resistant check, ICPL 332. In case of ICPL 98001, the 'b' value was greater than 1, and residual mean square equal to zero; indicating its adaptability to high-yielding environments (Eberhart and Russell, 1966). For ICPL 84060, ICPL 87119 and ICPL 187-1; the grain yields were unstable with zero RMS values and bi <1.

5.2 MECHANISMS OF RESISTANCE TO *H. armigera* IN PIGEONPEA

5.2.1 Antxenosis for oviposition

The numbers of eggs laid were greater on short-duration genotypes compared to the long-duration genotypes. This may be because of greater *H. armigera* population early in the season (September to October) than during the

later part of the season (November to December) when there is a slight decline in temperature. On pigeonpea, most of the eggs were laid on flowers and flower buds, and sparingly on the leaves (mostly during the vegetative phase of the host). In the field, the larval population was significantly greater on the top flowers and pods compared to the flowers and pods at middle and lower parts. Egg laying was quite high on floral parts and new pods as compared to foliage. Egg count was low on the *H. armigera* resistant lines such as ICPL 332, ICPL 84060, ICPL 87119, ICPL 88039, and T 21 compared to the susceptible genotypes (ICPL 87 and ICPL 87091). This suggested that oviposition nonpreference is one of the components of resistance to *H. armigera* in pigeonpea.

Sison *et al.* (1993) observed highest number of eggs on ICPL 87 as compared to the other genotypes tested. Egg and larval numbers have also been found to be lower on pod borer-resistant lines ICP 11964, ICP 1903, ICPL 84060, ICPL 87088, ICPL 87089 and ICP 1691 compared to the susceptible cultivar, ICP 1691 (ICRISAT, 1991). The number of eggs laid were more on genotypes with yellow flowers compared to the genotypes with red flowers. Similar observations have been reported by Laxmipathy (2000).

In the field, there was no relationship between the number of eggs laid and larval abundance ($r = 0.32$) and number of eggs and pod damage % ($r = 0.001$). Similar observations have also been made by Lateef (1985) and Srivastava and Srivastava (1989). A proportion of the larvae are possibly lost due to biotic and abiotic factors, and hence, it becomes difficult to obtain reliable data on larval density as a measure of genotypic resistance to this pest. Therefore, it is important to develop reliable techniques to screen for resistance to *H. armigera*

under laboratory and field conditions using uniform level of infestation at the most susceptible stage of the crop.

5.2.2 Antibiosis mechanism of resistance to *H. armigera*

The current study has shown that there is a significant variation in growth and survival of *H. armigera* reared on leaves, flowers and pods of different pigeonpea varieties. This is similar to the observations of Sison and Shanower (1994), who showed that the *H. armigera* larvae reared on leaves and flowers of pigeonpea had lower larval weights and longer development times than those reared on pods. Differences in the nutritional quality of different plant parts may account for the variation observed in the growth and survival of *H. armigera*. Bilapate *et al.*, (1988) showed that larval survival and adult fecundity were significantly greater on chickpea as compared to that on safflower, maize, cotton and pigeonpea. According to Vijaya Kumar and Jayaraj (1982), the preferred host plants are pigeonpea field bean, chickpea, tomato, cotton, chillies, mungbean and sorghum.

According to Dodia and Patel (1994), the larval and pupal mass of larvae *H. armigera* fed on developing pods of resistant varieties were significantly lower and the duration of the both the stages were longer than in larvae fed on the susceptible variety. The growth of larvae reared on flowers was faster than that on the pods.

Larval and pupal weights, and larval survival were greater in larvae reared on artificial diet containing lyophilized leaf and pod powders compared to the larvae reared on leaves, flowers and pods collected from field. This may be due to availability of more nutrients in the artificial diet. Reduced larval and pupal weights and prolonged larval and pupal periods were observed in insects reared on ICPL

332, ICPL 84060, ICP 7035, ICPL 88039 and T 21 as compared to the insects reared on ICPL 87 and ICPL 87091. These results indicated that antibiosis is one of the components of resistance to *H. armigera* in pigeonpea.

The larval growth was slower on diets containing the lyophilized leaf and pod powders compared to the standard diet. Similar observations have earlier been made by Yoshida and Shanower (2000), who indicated that the presence of growth inhibitors in the leaf and pod powder may result in reduced survival and slow growth of the larvae. Larval survival, pupal weights, pupation and adult emergence were lower on the resistant genotypes than on the susceptible ones, and the standard artificial diet. Slower larval growth, which resulted in prolonged development, may increase the probability of predation, parasitism, infection by pathogens, and slowdown population growth of *H. armigera* (Price *et al.*, 1980). Expression of resistance to *H. armigera* in artificial diet impregnated with leaves, flowers or pods of different pigeonpea genotypes were quite consistent. Therefore, impregnation of different plant parts consumed by the insect into the artificial diet can be used as a reliable means of evaluating pigeonpea genotypes for resistance to *H. armigera*. However, the results of such assays are slightly different than those observed with the intact plant parts. Therefore, efforts should be made to establish a clear cut relationship between laboratory data based on artificial diets impregnated with different plant parts and survival and development on intact plant parts and, overall expression of resistance to *H. armigera* under field conditions.

5.2.3 Trichome types and their density in pigeonpea genotypes

Trichomes play an important role in host plant resistance to insects (Peter *et al.*, 1995). Trichomes and their exudates and/or pod surface chemicals may

provide some protection against *H. armigera* damage (Romeis *et al.*, 1999b, Sharma *et al.*, 2001, Green *et al.*, 2002). Plant trichomes interfere with the searching behaviour of natural enemies of insect pests (Obrycki, 1986). Abundance of Type A trichomes and their exudates on reproductive structures also effect *H. armigera* natural enemies (Romies *et al.*, 1996, 1998). Glandular trichomes and their exudates also influence the activity and abundance of natural enemies (Sharma *et al.*, 2001). Different types of trichomes were present in the pigeonpea genotypes tested. The density of each trichome type differed significantly in pods and flowers. Genotypic differences and environmental factors affect the growth and development of trichomes (Southwood, 1986).

Type A and Type D type of trichomes were present in greater density in flowers and pods of the pigeonpea genotypes examined. In case of pods, Type 'D' trichomes were present in greater numbers compared to Type A trichomes. Trichomes were present in greater density towards the edges than in the middle areas of flowers and pods. Similar observations have been made by Romeis *et al.* (1996).

The pod borer, *H. armigera*, lays more than 80% of its eggs on pods and calyxes (Romeis, 1997). High density of nonglandular trichomes (Type A and Type B) might contribute to the larval mortality in the resistant genotypes ICPL 84060, ICPL 87119, ICPL 88039, ICPL 7203-1, ICPL 187-1 and T 21 although the cause and effect relationships needs to be established clearly.

The function of the Type B trichomes is unknown. Bisen and Sheldrake (1981) suggested that this is the source of characteristic fragrance. The secretions in the Type B-trichome are liberated only when the cell wall is ruptured. This could be caused by a chewing insect such as *H. armigera* or by abiotic factors

such as high temperatures or low air humidity (Ascensao *et al.*, 1995). Bisen and Sheldrake (1981) considered Type E trichome to be a developmental stage of type B. Since no intermediate forms between Type E and Type B are found, Type E is considered to be a separate trichome type.

Type C and D, trichomes on flowers and pods are nonglandular type, and were present in all the 12 genotypes examined. Type E trichomes were low or absent in a few genotypes. On the pods, Type D trichomes were greater in ICPL 187-1 than in ICP 7035.

5.2.4 Biochemical analysis

Nutritionally important constituents of a host plant play a significant role in the feeding behaviour of phytophagous insects (Beck and Hanec, 1958). The phosphorus and potassium contents in flowers and pods of the pigeonpea genotypes differed significantly. The levels of potassium and phosphorus were lower in pod borer resistant genotypes such as ICPL 332, ICPL 84060, ICPL 7035 and ICPL 187-1, but high in case of susceptible genotype, ICPL 87. Highest potassium content was observed in ICPL 87091 (susceptible genotype). Lowest potassium content was observed in ICPL 88039, which is a short-duration type and is relatively less susceptible to pod borer damage. Protein content was highest in ICPL 332, ICPL 7035, and ICPL 84060. ICPL 332, ICPL 84060, ICPL 7035, and ICPL 87119 which are long-duration types and hence tolerance or recovery to pod borer damage is one of the components of resistance. Because of high protein content, the damage by *H. armigera* may be more. Similar observations have been made by Khurana and Verma (1983). Highest sugar content was recorded in leaves and pods of ICPL 187-1 and lowest in ICP 7035 leaves and pods of T 21.

5.2.5 Bioassay of pod surface extracts from ICPL 87 (susceptible check) and ICPL 332 (resistant check) using glass fibre discs

The results of bioassay of pod surface extracts from ICPL 87 and ICPL 332 suggested that the compounds on the pod surface play an important role in feeding preference by larvae of *H. armigera*. The feeding indices and antifeedant activity confirmed that the compounds extracted from pod surface of ICPL 87 by either hexane or methanol stimulated the feeding by 3rd, 4th and 5th instars (Sharma *et al.*, 2001; Green *et al.*, 2002).

5.2.6 Bioassay using plant material

Larvae of *H. armigera* are able to distinguish between different plant parts, and between different species of *Cajanus*. Young larvae (1st/2nd instars) congregate inside flowers of *C. cajan* in preference to others plant parts (Green *et al.*, 2002). Older larvae (3rd to 5th instars) showed an increasing tendency to feed upon pods. Specially, switching from feeding primarily on flowers (up to the 3rd instars) to feeding upon both flowers and pods (4th and 5th instars) may be due to differences in nutritional requirements for different instars. Older larvae have increased appetite (Raubenheimer and Barton, 2000) and need more proteins (Simpson *et al.*, (1988), and this may be one of the factors responsible for a change in feeding behaviour of different larval instars.

The 3rd instar larvae feed more on flowers and pods compared to the leaf material. This observation was common for all the genotypes. The 3rd instar larvae spent more time on flowers and pods than on leaves. Among all the pigeonpea genotypes tested, there was high damage in flowers and pods of the

susceptible genotypes such as ICPL 87 and ICPL 87091. These observations were similar to genotypic reaction under field conditions. In case of ICPL 84060, ICPL 332, ICP 87119, ICP 7035, ICPL 88039, and ICPL 187-1, lower pod damage was observed both under field and laboratory conditions. This indicates that the larvae are able to select the nutritionally more optimum food when a choice is offered between a resistant and a susceptible genotype.

Differences in pod surface chemistry, that resulted from extraction of pod surface compounds in different solvents affected the behaviour of *H. armigera* larvae. In case of resistant genotypes such as ICPL 84060, ICPL 88039, ICP 7203-1 and ICPL 98008, more damage was observed in pods extracted in hexane than in the control pods. The results of these studies suggested that the compounds on the pod surface of pigeonpea genotypes play an important role in acceptance or rejection of food by *H. armigera* larvae.

5.3 TOLERANCE

Damage by *H. armigera* larvae on pigeonpea during the vegetative stage was very low. However, during the reproductive stage, the larvae damaged the flowers and developing pods. There was a significant and positive correlation between the larval population and pod damage ($r = 0.585$).

Pigeonpea genotypes with indeterminate growth habit were less susceptible than the genotypes with determinate growth habit. Greater infestation on the determinate plant types may be because of the fact that such genotypes have clustered flower arrangement, which might facilitate easy access to flowers/pods to the borer larvae, e.g., in ICPL 87 and ICPL 87091. These observations were similar to the findings of Kushawaha and Malik (1988).

Significantly higher grain yield was recorded in ICPL 187-1, ICPL 332, ICPL 84060, ICPL 7203-1, ICPL 87119, ICPL 98001, T 21 and ICPL 88039 under protected conditions as compared to ICPL 87. Under unprotected conditions, high grain yield was recorded only in case of ICPL 84060 and ICPL 187-1.

The pod damage was 62.6% under unprotected conditions and 13.9% under protected conditions. The pod damage in ICPL 87 and ICPL 87091 was high under both protected and unprotected conditions. Both of these genotypes were of determinate type, and short- duration varieties. Indeterminate growth habit coupled with long-duration resulted in less *H. armigera* damage.

Under unprotected conditions, the grain yield of ICPL 187-1 was on par with that of the resistant check, ICPL 332. ICPL 98008, T 21 and ICPL 87119 were on par with each other. Under protected conditions, all the genotypes were on par with the resistant check, ICPL 332 in terms of pod borer damage. Under unprotected conditions, ICPL 7035 (24.4%) was on par with the resistant check, ICPL 332 (22.9%) for pod damage. These observations suggested the presence of tolerance mechanism of resistance in pigeonpea to *H. armigera* damage. Loss in grain weight was lowest in ICPL 332, followed by ICPL 84060, ICPL 187-1, ICPL 87091, ICPL 87119, ICPL 88039, ICPL 98001, and T 21.

Chapter VI

SUMMARY

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SUMMARY

The present investigation on "Mechanisms of Resistance to *Helicoverpa armigera* (Hubner) in pigeonpea [*Cajanus cajan* (L.) Millsp.]" was conducted at ICRISAT Patancheru during 2000-2002. The results are summarized as follows:

1. There was a strong genotype x environment interaction for *H. armigera* damage and most of the genotypes were unstable across environments in terms of grain yield, except ICPL 332 (resistant check).

2. Among the genotypes tested, high grain yields were recorded in ICPL 84060, ICPL 87119, ICPL 332, ICPL 98008 and ICPL 187-1.

3. Lowest pod damage was recorded in ICPL 187-1 (39%), followed by resistant check ICPL 332, ICPL 84060 and ICPL 88039 (47-53%, pod damage).

4. All the genotypes were unstable in their reaction to *H. armigera* in terms of percentage pod damage. However the regression coefficient was less than unity in case of ICPL 187-1, ICP 7203-1, ICPL 88039, ICPL 98008, T 21 and ICPL 332, while ICPL 87091, ICPL 87119 and ICPL 87 had regression coefficients greater than unity and these genotypes suffered greater pod damage with increase in the intensity of *H. armigera* infestation.

5. Studies on oviposition preference under no-choice, dual-choice and multi-choice conditions revealed that among medium and long duration genotypes; ICPL

332 (resistant check). Among the short-duration genotypes; the susceptible check ICPL 87 was preferred most, followed by ICPL 87091, ICP 7203-1, ICPL 88039 and ICPL 98001.

6. Reduced larval and pupal weights, prolonged larval and pupal development on resistant genotypes (ICPL 332, ICPL 84060, ICP 7035, ICPL 187-1, ICPL 88039 and ICP 7203-1) compared to the susceptible genotypes (ICPL 87, ICPL 87119 and ICPL 87091) indicated that antibiosis is one of the components of resistance to *H. armigera* in pigeonpea. These results suggested that a growth inhibitor or antifeedent substance or both existed in the resistant genotypes.

7. Five morphologically distinct trichomes (Type A, B, C, D and E) were identified from pods and calyxes of the 12 pigeonpea genotypes. Type A and B trichomes were present in greater density in flowers and pods. In case of pods, Type D trichomes were present in greater numbers as compared to Type A. High density of glandular trichomes (Type A and Type B) might contribute to the larval mortality on the resistant genotypes (ICPL 84060, ICPL 87119, ICPL 88039, ICP 7203-1, ICPL 187-1 and T21).

8. The pod surface extracts of ICPL 87 and ICPL 332 stimulated feeding by the third- fourth-and fifth-instar larve of *H. armigera* when presented at pod surface equivalents. The attraction of *H. armigera* larvae to ICPL 87 and ICPL 332 plant extracts might be due to some chemical compounds present in the pod surface extracts.

9. Among the 12 genotypes tested, the amounts of potassium and phosphorus were lower in resistant genotypes such as ICPL 332, ICPL 84060, ICP 7035 and ICPL

187-1, but high in the susceptible check, ICPL 87. Protein content was quite high in the pod borer resistant genotypes (ICPL 332, ICP 7035 and ICPL 84060). Because of high protein content, the damage by *H. armigera* may be more, but low phosphorus and potassium contents may influence the extent of feeding.

10. Studies on yield loss under protected and unprotected conditions revealed tolerance as one of the mechanisms of resistance to *H. armigera*. Reduction in grain yield was lower in resistant check ICPL 332, followed by ICPL 84060, ICPL 87 and ICPL 87119 indicating tolerance to pod borer damage in these genotypes.

The lines showing high and stable resistance to *H. armigera* can be used in pigeonpea improvement programs. The resistance mechanisms involved in these genotypes can be exploited to develop varieties resistant to *H. armigera* in pigeonpea.

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