# HOST PLANT RESISTANCE STUDIES IN PIGEONPEA GENOTYPES AGAINST *Helicoverpa armigera* (Hub.)



**THESIS**

**Submitted to**
**Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola**
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## DECLARATION OF STUDENT

I hereby declare that the experiment work and its interpretation of thesis entitled **"HOST PLANT RESISTANCE STUDIES IN PIGEONPEA GENOTYPES AGAINST *Helicoverpa armigera* (Hub.)"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis of publication of any University or scientific organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

**Place: Akola**

**Date:** 26/12/2013

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Enrolment No.G / 169

# CERTIFICATE

This is to certify that the thesis entitled **"HOST PLANT RESISTANCE STUDIES IN PIGEONPEA GENOTYPES AGAINST *Helicoverpa armigera* (Hub.)"** submitted in partial fulfilment of the requirement for the degree of **Doctor of Philosophy in Agriculture (Agril. Entomology)** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Patil Subhash Sitaram** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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Date : 26.12.2013

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

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**Place: Akola** **(Patil Subhash Sitaram)**

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## (E) ABBREVIATIONS

| | | |
|---|---|---|
| % | - | Per cent |
| / | - | Per |
| C.D. | - | Critical differences |
| Cm | - | Centimeter |
| Crude pro | - | Crude protein |
| $^0C$ | - | Degree Celcius |
| Av. | - | Average |
| d.f. | - | Degree of freedom |
| Deptt. | - | Department |
| DR | - | Damage Rating |
| Dr. PDKV | - | Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola |
| e.g. | - | Exampli gratia (For example) |
| et al. | - | et alia (and others) |
| etc. | - | Etcetera |
| Fig. | - | Figure |
| G | - | Gram |
| $ | - | Dollar |
| Ha | - | Hectare |
| hrs | - | Hours |
| i.e. | - | That is |
| IPM | - | Integrated Pest Management |
| J. | - | Journal |
| Kg | - | Kilogram |
| LPB | - | Lepidopteron Pod Borer |
| M | - | Million |
| M / ha | - | Million per hectare |
| max. | - | Maximum |
| Min. | - | Minimum |
| $m^2$ | - | Square meter |

| | | |
|---|---|---|
| MS | - | Mean square |
| MSe | - | Error mean squares |
| MT | - | Metric Tonnes |
| M.S.L. | - | Mean Sea Level |
| No. | - | Number (s) |
| PSR. | - | Pest Susceptibility Rating |
| q/ha | - | Quintals per hectare |
| r | - | Correlation Coefficient |
| R.H. | - | Relative humidity |
| R | - | Resistant check |
| S | - | Susceptible check |
| Sci. | - | Science |
| SE | - | Standard Error |
| SE(d) | - | Standard error of difference |
| SE(m) ± | - | Standard error of mean |
| Sr. No. | - | Serial number |
| Spp. | - | Species |
| temp | - | Temperature |
| Un pub. | - | Unpublished |
| *Viz.*, | - | Videlicet (namely) |
| Vol. | - | Volume |
| Vs | - | Versus |
| S | - | Standard deviation |
| S | - | Summation |
| $s^2$ | - | Variance |
| Wt. | - | Weight |

## (F) THESIS ABSTRACT

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### ABSTRACT

The present investigations entitled "Host plant resistance studies in pigeonpea genotypes against *Helicoverpa armigera* (Hubner)." Were carried out in Department of Agril. Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the year 2011-12 and 2012-13.

Twenty four genotypes of pigeonpea were screened for resistance against *H. armigera* (Hubner) under field conditions replicated

thrice in RBD. Among the 24 genotypes tested lowest pod damage was recorded in ENT-11 (5.97%) followed by resistant check ICPL-332 (9.75%), ICPHRL-4979-2 (13.08%), ICPL-97253 (13.90%), ICPL-909 (13.92%) and PPE-45-2 (14.08%). Highest pod damage was registered in the susceptible check ICPL-87 (24.33%) followed by BSMR-736 (22.17%).

Mechanisms of resistance (antixenosis for oviposition, and antibiosis) to *H. armigera* in 24 pigeonpea genotypes were studied in laboratory conditions. Oviposition studies under no-choice, dual-choice and multi-choice conditions revealed that, oviposition was significantly lower on ENT-11, ICPL-332, ICPHRL-4979-2, ICPL-909, ICP-10531, ICP-13198, ICPHRL- 4985-10, PPE-45-2, ICPL-97253, ICPL-87119 and ICPH-2740 when compared with that on the susceptible check ICPL-87due to biophysical traits and certain biochemicals.

The antibiosis mechanism of resistance to *H. armigera* was measured in terms of larval mortality, reduced body weights, prolongation of larval period, pupal weight, per cent pupation, average per cent of adult emergence, growth index, female male ratio, average fecundity per female, percent hatchability of eggs, and adult longevity by rearing larvae on the flowers and pods of different pigeonpea genotypes. There was an increasing trend when the larvae were reared on the flowers and pods of resistant genotypes of pigeonpea ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253. The larval and pupal weights on the resistant genotypes were significantly lower(284.33mg and 171.67mg, respectively) than those reared on the susceptible pigeonpea genotypes ICPL-78(363.33mg and 280.00mg,respectively), ICPL-20118, BSMR-736, ICPL-99004 and ICPHRL-4985-1 indicating the presence of antibiosis component of resistance to *H. armigera* in resistant genotypes compared to susceptible genotypes.

Four types of trichomes viz. type A, type B, type C and type D, were identified on the calyxes and pods of the 24 pigeonpea genotypes. Of the four trichomes, type A and type B were found to be glandular, and type C and type D were non-glandular in nature. Type A (26.00) and type D(48.68) trichomes were present in greater quantity in flowers and pods

Type A (49.00) Type D (58.33) of the pigeonpea genotypes examined. In case of pods, type D trichomes were present in large numbers compared to type A trichomes. High density of nonglandular trichomes (type C and type D) might contribute to the larval mortality in the resistant genotypes ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE45-2, ICP-13198, ICPL-97253 ICP-990016 and ICPL-20062

The biochemical components in pigeonpea genotypes imparted resistance and exercised great influence on infestation of pest. The present studies indicated that high levels of resistance to *H. armigera* in resistant genotypes of pigeonpea ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253 might be due to lower amounts of sugars (6.93%) and proteins (13.47%) and high content of tannins (17.93/g), phenols(84.37mg/g), and flavonoids(7.78mg/g). The quantity of total soluble sugar was high in the susceptible genotypes of pigeonpea ICPL-78 (10.67%), ICPL-20118, BSMR-736, ICPL-99004 and ICPHRL-4985-1 compared to the resistance genotypes.

*H armigera* (Hubner) showed less feeding preference towards the ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253 (1.55 to 3.23 damage rating) pigeonpea genotypes, where the per cent damage was low compared to that on the pods of susceptible pigeonpea genotype, ICPL-87 (6.07 damage rating). The biochemical composition might be responsible for their acceptance or rejection as food by the H. *armigera* larvae.

# CHAPTER I

# INTRODUCTION

## 1.1 Background information

Pigeonpea (*Cajanus cajan* (L.) Millsp.), is known as redgram, *arhar* and *tur*, is one of the major grain legumes in the sem-iarid tropics (SAT) (Nene et al., 1990). In India, it is the second most important pulse crop after chickpea.

Globally, pigeonpea is cultivated in 4.92 million hectares with an annual production of 3.65 million tones and an average productivity of 898 kg/ha. (Choudhary et al., 2013). The countries in the Indian subcontinent, Africa and Central America are dominant producers of this pulse crop. In India, it is mainly cultivated as rainfed crop in about 3.92 million hectares with the production of 2.8 million tones, accounting for more than 80 per cent of the global pigeonpea production. Major pigeonpea growing states in India include Uttar Pradesh, Maharashtra, Madhya Pradesh, Gujarat and Karnataka. In Maharashtra area under this crop is 1.20 million ha. with production of 0.91 million tonnes. Vidarbha region of Maharashtra contributes a major pigeonpea growing area of 0.60 million ha. with the production of 0.38 million tones (Anonymous, 2012).

Productivity of pigeonpea has remained static over the past several decades because of many reasons; and, heavy damage by insect pests is one of them. More than 200 insect species have been reported to feed on this crop, of which pod borer *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is the most devastating pest in the semi-arid tropics (SAT) worldwide (Sharma et al., 2008) and causes significant losses in grain yield (Anitha Kumari et al., 2006), and in severe cases may cause complete crop loss (Reed and Lateef, 1990). Over the past decade, three outbreakes of this pest were recorded, the latest being in 1997 in Gulbarga, which is known as the pulses bowl of Karnataka. *Helicoverpa armigera* (Hubner) is reported to cause 50 to 60 per cent grain loss in pigeonpea. During 1997-98, pigeonpea suffered a complete loss due to *Helicoverpa armigera* (Puri, 1998). On an average, pod borer caused 90-

100 per cent yield loss in 1992-93 and 1997-98 (Yelshetty and Gowda, 1998). Annual yield losses due to this pest have been estimated to be over US$2 billion in the semi-arid tropics (Sharma, 2005) and 300-400 million per annum in India alone.

**1.2 Importance and need of study**

Pigeonpea is mainly grown during *kharif* season. Traditionally grown pigeonpea plant types are of long duration (180-300 days to maturity) and also are maintained as perennials (Nene et al., 1990). Recently there is increasing emphasis on short duration cultivars, in which the first flush of pods can mature within 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., 2002) central and peninsular India (Nam et al, 1993).

Pigeonpea is an important source of high quality dietary protein. It is consumed in the form of split pulse and plays a significant role in the nutritional security of the overwhelming majority of vegetarian people of the Indian sub continent. Analysis of pigeonpea dal (split pulse without husk) reveals protein content of 22.3, fat (ether extract) 1.7, mineral matter 3.6, , carbohydrate 57.2, calcium 9.1, phosphorus 0.26 per cent, carotene evaluated as vitamin A 220 IU and vitamin $B_1$ 150 IU per 100g. Sun-dried seeds of pigeonpea contains (per 100g) 345 calories, 19.5g protein, 1.3g fat, 65.5g carbohydrates, 1.3g fiber, 3.8g ash, 161mg calcium, 285mg phosphorus, 15mg iron, 55µg ß- carotene equivalent, 0.72 mg thiamine, 0.14mg riboflavin, and 2.9mg niacin (Duke, 1983).

Besides being a rich source of protein, pigeonpea maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in furthering sustainable agriculture (Kannaiyan, 1999). In Thailand and North Bengal, pigeonpea serves as host for the scale insect which produces lac or stick lac. In Malagasy the leaves are used as food for the silkworm (Duke, 1983). Pigeonpea stalks are also a major source of firewood and live stock feed. This pulse crop is grown mostly as an intercrop between cereal crops and cotton in Maharashtra and plays a unique role in enriching the soil, by adding 40 kg nitrogen per hectare over a given season. The deep root system of the crop helps to recycle plant

nutrients from deeper layers, and the acid secretions from its roots increase the availability of phosphorus in the soil. Pigeonpea also improves the physical structure of soil by enhancing water infiltration for subsequent crops and plays a crucial role in sustaining agriculture in rainfed, semi arid farming systems (Arunachalam et al., 1995).

*Helicoverpa armigera* (Hubner) is a polyphagous pest occurring throughout Africa, Middle East, Southern Europe, India, Central and South Eastern Asia, Eastern and Northern Australia, New Zealand and many Pacific Islands (Fitt, 1989). The cosmopolitan occurrence of this pest has accentuated the problem globally. It is considered as major biotic constraint in increasing the pigeonpea production. *Helicoverpa armigera* (Hubner) has attained the key pest status due to its direct attack on fruiting bodies, voracious feeding habits, high mobility and fecundity, multivoltine and overlapping generations with facultative diapauses, nocturnal behavior and migration, host selection and propensity for acquiring resistance against insecticides (Satpute and Sarode, 1995; Sarode, 1999).

*Helicoverpa armigera* (Hubner) has a wide host range. It feeds on more than 300 plant species of which pigeonpea is highly preferred. Prior to 1975, less than 20 per cent farmers used insecticides on pigeonpea. However, 1993 onwards adoption of insecticides for pest management on pigeonpea increased considerably. Due to widespread use of insecticides pod borer has developed considerable levels of resistance to conventional insecticides including synthetic pyrethroids (Armes et al, 1992). Activity of natural enemy on *Helicoverpa armigera* on pigeonpea is quite low as compared to that on other crops like sorghum (Bhatnagar, 1980). There is greater survival of this pest on pigeonpea and as a result there is a heavy loss in grain yield. Thus, there is a need to think over the alternate, eco-friendly and strategic components of IPM to combat menace.Exploitation of host plant resistance has got an immense importance as it is a basic component of IPM and other tactics are built up on it (Dadmal et al., 2003).

During the course of evolution, plant acquires several defense mechanisms against insect pests. The ability of plant to withstand attack of pest is due to certain phenotypical/ genotypical or biochemical

characteristics that exert unfavorable effects on the insect pest. Painter (1951) described three mechanisms of host plant resistance *viz.* antixenosis (non-preference), antibiosis, and tolerance. 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 behavior and physiology, resistance has been differentiated in terms of antixenosis, antibiosis and tolerance, more antibiosis than antixenosis or tolerance has been reported in legume crops (Clement et al., 1994).

It has long been recognized that host plant resistance is one of the most effective option for pest management, and pigeonpea cultivars with resistance to *H. armigera* would provide an effective complementary approach to control this pest. Identification and utilization of cultivars with resistance/tolerance to *H. armigera* would not only help in reducing the extent of losses due to this pest, but also reduce the number of insecticide sprays required to control this pest on pigeonpea. Screening of more than 15,000 accessions of pigeonpea germplasm for resistance to *H. armigera* has revealed very low levels of resistance to this pest (Sharma, 2005). Antixenosis and antibiosis are the major components of resistance to pod borer, *H. armigera* in pigeonpea ( Anitha Kumari et al., 2010[a]). Some of the wild relatives of pigeonpea have shown high levels and biochemical components of resistance to *H. armigera*. Wild type, *Cajanus acutifolius* is one relative in the secondary gene pool of pigeonpea which has shown resistance to the pest (Sujana et al., 2008). Development of cultivars resistant to this pest has a greater potential for integrated pest management, particularly under subsistence farming conditions in the developing countries (Fitt, 1989).

The mechanism of resistance in pigeonpea genotypes to *H. armigera* (Hubner) has been identified in terms of slower larval growth, longer pupation time, and reduced larval and pupal weights (Lateef et al., 1981; Saxena et al., 1990; Shanower et. al., 1997). Presence of antifeedant or growth inhibiting compounds and/or poor nutritional quality may be responsible for the antibiosis mechanism of resistance to *Helicoverpa armigera* resistant genotypes of pigeonpea (Yoshida and Shanower, 2000).

However, most of the genotypes of pigeonpea showing resistance to *H. armigera* have not been characterized for different mechanisms such as oviposition preference, antifeedant/ phagostimulant effects on larvae and antibiosis. Therefore, measurement of different mechanisms in genotypes of pigeonpea to *H. armigera* is highly important to identify genotypes with different mechanisms to develop cultivars with high and stable resistance to this pest. In view of the importance of this crop, immense damage potential of *H. armigera*, development of resistance in this pest to insecticides and to have the eco-friendly management of this pest the present investigations have been carried out with the following objectives.

**1.3 Objectives of study**

1. Screening of pigeonpea genotypes against *Helicoverpa armigera* (Hubner).
2. To study antixenosis and antibiosis mechanisms of host plant resistance in selected pigeonpea genotypes against *Helicoverpa armigera* (Hubner).
3. To find out the morphological and biochemical bases of host plant resistance in selected pigeonpea genotypes.

**1.4 Scope and limitation**

*H. armigera* (Hubner) has developed high levels of resistance to insecticides; it has become difficult to control this pest on pigeonpea and several other crops with conventional insecticides (Kranthi et al., 2002; Sharma, 2005). Insecticide application for *Helicoverpa armigera* (Hubner) is uneconomical under subsistence farming and is largely beyond the means of resource poor farmers. Therefore, host plant resistance assumes a pivotal role in managing *H. armigera* (Hubner) damage either alone or in combination with other methods of control. Insect resistant varieties manage pest at essentially no cost to farmers (Panda and Khush, 1995). This approach holds great potential in pigeonpea. Host plant resistance is an important component of integrated pest management (IPM) and is well suited to the environment conditions of the semi arid tropic. Host plants 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 behavior of *Helicoverpa 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 extract or pod surface chemicals may also provides some protection against *Helicoverpa armigera* damage. Acetone extract of *C. scarabaeoides* pod surface include a weak, but significant feeding inhibitor (Romeis, 1997).

Several morphological traits such as pod toughness, structure of pod wall, and trichomes on the pod surface have been reported to be associated with resistance to *H. armigera* (Shanower et al., 1997). Besides the morphological traits, chemical compounds in trichome exudates and on pod wall surface also influence the host plant selection and colonization by *H. armigera* (Hartlieb and Rembold, 1996; Green, et al. 2002, 2003). In addition, pigeonpea also contains anti-nutritional factors such as proteinase inhibitors, oligosaccharides, phenols, tannins and phytic acid (Singh, 1988), which may influence the host plant suitability to *H. armigera*.

Knowledge of the resistance mechanisms and associated factors involved is essential for effective utilization of sources of resistance in breeding programmes. 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 particular genotypes of pigeonpea. Therefore, development, selection and use of high yielding and insect pests' tolerant genotypes are an urgent need of the day.

Plant resistance is not a panacea for solving all the pest problems. Certain limitations and problems will always beset any insect program and HPR is no exception. The major limitations of plant resistance are: *viz.* it takes a long time to identify and develop insect resistant cultivars, absence of adequate levels of resistance in the available germplasm may deter the use of plant resistance for managing certain pest, despite many dramatic successes in HPR, cases still exist where

plant resistance to *Helicoverpa armigera* may lead to increased susceptibility to another insect. Most of the pigeonpea genotypes with resistance to *H. armigera* are susceptible to *Fusarium* wilt (Lateef and Sachan, 1990). Plant resistance at times may be associated with low yield or factors resulting in poor or unacceptable produce. In such situations, one has to break the linkage between the factors conferring resistance to the target insects and the low yield potential or arrive at the threshold levels for resistant traits that result in reduced pest susceptibility, and at the same time do not have adverse effect on the quality of produce (Sharma, 2005).

**1.5 Hypothesis**

The identification and utilization of cultivar's resistance/ tolerance to *Helicoverpa armigera* (Hubner) would have number of advantages, particularly for a relatively low value crop, such as pigeonpea. Screening of germplasm (more than 15,000 pigeonpea accession) for resistance to *H. armigera* has revealed very low levels of resistance to this pest (Sharma, 2005). 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). However, these germplasm lines have not been characterized for diversity and mechanism of resistance to this pest. Although several genotypes with resistance to *Helicoverpa armigera* have been reported, little progress has been made in incorporating resistance into cultivars with acceptable grain yield and quality. Use of resistance/tolerance gean/ geans either in vertical or horizontal resistance HPR plays an important role ultimately to develop tolerant or moderately resistant varieties. Besides, such genotypes check the pest population generation after generation with its antibiosis and antixenosis mechanism.

In view of the above, the present investigation would be helpful in formulating the IPM modules against *Helicoverpa armigera* and for breeders to develop resistant crosses by utilizing source of resistance. Besides, biochemical studies on different pigeonpea genotypes would be helpful as a marker to judge the resistant, tolerant and susceptible cultivars.

CHAPTER II

# REVIEW OF LITERATURE

Keeping in view the objectives of the research work, the literature have been reviewed as regards to screening of pigeonpea genotypes under field conditions and antixenosis, antibiosis and tolerance mechanisms, bio-chemical and morphological attributes in the various pigeonpea genotypes.

The literature thus collected for planning of the experiments and for presenting the results is given here, under the respective headings and subheadings.

## 2.1 Screening of pigeonpea genotypes for their reaction against *Helicoverpa armigera* (Hubner) under field conditions:

Bhosale and Nawale (1983) studied the relative susceptibility of 40 entries of pigeonpea to attack by larvae of *H.armigera* in field plot tests in Rahuri during 1978. They reported that, none of the entries were free from infestation, but those least susceptible were ICPL nos. 148, Hy-2, 4725, Phule T-1, AS-71-37, Phule –T-3, 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.

Naresh et al. (1983) observed that in general extra-early and determinate type genotypes were more susceptible to pod borer damage.

Lateef (1985) reported that the levels of resistance to *H.armigera* in germplasm accessions were low to moderate. This has necessitated the need for selecting genotypes with greater ability to tolerate or recover from the pod damage.

Kushwaha and Malik (1987) reported that determinate genotypes show greater susceptibility to pod damage by *Helicoverpa armigera* than indeterminate types. One of the reasons for high susceptibility of determinate type genotype to *Helicoverpa armigera* may be due to cluster type of flowering making it easier for larvae to move from one pod to another.

Patnaik et al. (1989) screened eleven pigeonpea genotypes (ICPL Nos. 94, 154, 151, 289, 184, 146, 8317, 8322, 351, 267, and 148) for resistance to *H.armigera*, which were of early maturity group and determinate type of growth habit. They noted the mean pod damage over three years, indicated that ICPL-154 and ICPL-94 had low levels of pod damage of 9.8 and 10.9 per cent, respectively, as compared to the other test cultivars.

Lateef and Pimbert (1990) screened the entire ICRISAT pigeonpea collection of more than 14,000 pigeonpea accessions for reactions against *Helicoverpa armigera* and several genotypes were identified which had consistently lower pod damage viz. ICPL-1, ICPL-2, ICPL-269, ICPL-187-1, ICP-909-E3, PPE-45-2, ICP-1811-E3, ICP-1903-E1, ICP-10466-E3, ICP-3615, ICP-5036, PPE-37-3, ICP-8094-2-S2, and ICP-8102-5-S1.

Patel and Patel (1990) screened 13 early and 13 midlate maturing varieties of pigeonpea against *H.armigera* and other pigeonpea pests. None of the entry was completely free from the infestation of *H.armigera*.

ICRISAT (1992) reported that variety ICPL-332 is tolerant to pod borer *H.armigera* and was having an average 35 per cent borer damaged pods as against the cultivars C-11 (51% borer damaged pods) and BDN-1 (65% borer damaged pods) in pesticides free fields at ICRISAT.

Raut et al. (1993) conducted field screening of pigeonpea germplasm against pod borer complex. They observed entry H-84-14 had lowest grain infestation. Whereas, maximum damage was recorded in ICPL-317. The CORG-13, H-84-14, CO-5, ICPH-8, MTH-6, BON-33 and MTH-66 gave higher yield than the other entries. The total loss in grain yield varied from 8.68 to 54.84 per cent.

Sahoo and Patnaik (1993) evaluated eight genotypes from extra early duration (90 to 100 days). They reported that these cultivars were attacked pod borer at various stages of pod development and observed that none of the cultivars were free from infestation. The extra early maturing cultivars had the highest pod damage due to *H. armigera*

(ICPL-87, 29.6% damage) followed by the early and late maturing cultivars (C-11 with17.2% pod damage).

Patel et al. (1994) studied field screening of pigeonpea genotypes against pod borer and podfly. They found that among seven genotypes, GAUT-82-90 was the least susceptible genotype to all three insect pests, i.e. *H. armigera* and other pest with the highest yield potentials.

Durairaj and Ganapathy (1997) screened cultivated and wild relatives of pigeonpea for identifications of resistance to *Helicoverpa armigera*. The study revealed that several germplasm accessions showed moderate resistance to *Helicoverpa armigera*.

Lal and Rathore (1999) screened 2033 accessions of pigeonpea against pod borer for three years and found that PDA 88- 2E, PDA 89- 2E, PDA-92- 1E, PDA 93- 1E, T-21, NP 15, ICPL 4, ICPL 91031, ICP 8860 and PPE-45-2 has moderate resistance to *Helicoverpa armigera*.

Dahiya et al. (2001) conducted the field screening study on many short duration pigeonpea germplasm and reported that within short duration determinate types, ICPL- 289 and H- 81- 95 had less susceptibility to pod borer.

Srivastava and Mohapatara (2002) screened fifteen medium duration genotypes for the extent of damage due to lepidopteran pod borers (LPBs). The extent of pod damage inflicted by LPBs varied from 1.0 to 6.3 per cent. Pest susceptible rating (PSR) showed that the genotype ICP-8863 suffered the highest pod damage caused by LPBs, while lowest was in KM-124 and KM-125.

Surana et al. (2002) conducted a field trial to determine the reaction of pigeonpea genotype to *Helicoverpa armigera* and other pests. Pigeonpea cultivars C- 11, ICPL- 87119, WRG- 47, WRG- 53, TAT- 9629, BDN- 704, AKT- 9726 and BSMR- 736 were tested. Cultivars C-11, ICPL-87119, WRG-47 and WRG- 53 had more damage due to pests compared to the other cultivars. The highest yield and yield potential was exhibited by WRG- 47 (802 kg/ ha) followed by TAT- 9629 (790 kg/ha).

Several genotypes were identified, that consistently had lower pod damage. However, these genotypes had not been widely used

because the levels of resistance were too low, and less preferred agronomic characters (Sharma et al., 2003).

Ujagir et al. (2005) conducted field trial for screening of 28 genotypes with Bahar and C11 as check against *Helicoverpa armigera* at Crop Research Centre of G.B. Pant Univ. of Agri. & Tech., Pantnagar during *kharif* seasons of 2001-2002 and 2002-2003. On the basis of mean total pod damage of two years, the lowest pod damage of 74.7per cent in ICC 13199 and highest of 97.4per cent in ICC 7182 was recorded with 90.5 to 92.4 per cent in check cultivars.

Kooner and Cheema (2006) screened eighty nine genotypes of pigeonpea for four years (2001-2004) to isolate sources of resistance to pod borers. On the basis of per cent pod damage and Pest Susceptibility Rating (PSR), entries AL-1498, AL-1502 and Al-1340 were found promising with mean pod damage of 11.21 to 13.71 per cent (PSR 3-3.50) as compared to17.67 to 26.25 per cent (PSR 4-5.50) in the check varieties (AL-15, AL-201 and T-21) and 28.21 per cent (PSR 6.00) on the infester and used resistant donors in the crossing programme to evolve pod borer resistant/tolerant varieties of pigeonpea. Therefore, genotypes AL-1498, AL-1502 and AL-1340 could be used as resistant donors in the crossing programme.

Rizwana Banu et al. (2007[c]) screened fifteen germplasm lines for their resistance/tolerance to pod borer under natural infestation in pesticide-free open field. The pod damage per cent was calculated on the basis of number of pods examined and the number of infested pods. On the basis of mean infestation, ICP-13201 showed the lowest 25 per cent pod damage and showed lowest susceptibility among the genotypes studied. It was followed by ICP-13208 and ICP-11964 showed lower pod damage. The rest of the genotypes suffered higher pod damage to *Helicoverpa armigera*. Considering the yield potential ICP-13201, ICP-13214 and ICP-13212 showed higher yield potential than other genotypes. Considering the lower susceptibility to *H. armigera* and higher yield potential ICP-13201 was found to be the best.

Seventy two inter-specific plants progenies, derived by crossing wild species viz. *C. cajanifollous*, *C. acutifolius* and *C.*

*scarabaeoides* and cultivated lines viz. UPAS-120, Pant A-134, and ICPL-84023, in field to isolate sources of resistance to pod borer (*H.armigera*). On the basis of pest susceptibility reaction all 24 $F_3$ populations derived by utilizing wild species *C. scarabaeoides* were found highly resistant (HR) for pod and seed damage due to pod borer in protected as well as unprotected conditions as compared to cultivated parents. Though moderately susceptible reaction (MS) was recorded in $F_3$ population of UPAS-120 X *C. auctifolius*. $F_3$ progenies of ICPL-84023 X *C. cajanifolius* and UPAS-120 X *C. cajanifolius* were noted highly resistant (HR) for pod as well as seed damage even in unprotected condition. However, two progenies of Pant A-134 X *C. cajanifolius* showed least susceptible reaction (LS) in unprotected condition. In general, all 72 $F_3$ progenies of nine inter specific hybrids evaluated for their reaction to the infestation of pod borer showed very low level of pod and seed damage as compared to pod and seed damage in cultivated lines (Gangwar et al., 2009).

Anitha Kumari et al. (2010[b]) evaluated a set of twelve diverse genotypes for resistance to *H. armigera* for two years over four plantings under natural infestation. There were significant differences among the genotypes in numbers of eggs and larvae, percentage pod damage, visual damage rating, and grain yield. The genotypes ICPL 187-1, ICP 7203-1, ICPL 98008, T 21, ICP 7035, and ICPL 332 exhibited moderate levels of resistance to *H. armigera* across planting dates, although there were a few exceptions. ICPL 187-1, ICP 7203-1, ICPL 84060, ICPL 87119 and ICPL 332 also showed better grain yield potential than the susceptible checks, ICPL 87 and ICPL 87091. All the genotypes were stable in their reaction to pod borer damage based on visual damage rating (except ICPL 87119 and ICPL 84060), but unstable for per cent pod damage. Grain yield of most of the genotypes under *H. armigera* infestation was also unstable, except that of ICPL 87119, ICP 7035 and ICPL 332.

**2.1.1 Yield performance of different pigeonpea genotypes**

Dahiya and Singh (1993) screened twenty nine pigeonpea genotypes for yield. Six genotypes viz. C-11, ICPL-187-1, PPE-45-2, ICPL-87119, ICPL-296, ICP-5036 and ICPL-148 exhibited stable yield.

Surana et al. (2002) conducted a field trial to determine the reaction of pigeonpea genotype to *Helicoverpa armigera* and other pests. Pigeonpea cultivars C- 11, ICPL- 87119, WRG- 47, WRG- 53, TAT- 9629, BDN- 704, AKT- 9726 and BSMR- 736 were tested. The highest yield and yield potential was exhibited by WRG- 47 (802 kg/ ha) followed by TAT-9629 (790 kg/ha).

Jayashri Ughade (2006) screened twenty six genotypes for their resistance/tolerance to pod borer under natural infestation in pesticide-free open field during 2004- 2005 at Parbhani. Considering the yield potential WRG-53 (2046),Bahar (1800 kg/ha), LRG-41(1768 kg/ha), PT-332 (1719.5 kg/ha), BDN-2003-1(1609kg/ha), AKT-8811(1607kg/ha) and ICPL-332(1537kg/ha) showed higher yield potential than other genotypes.

Rizwana Banu et al. (2007[c]) screened fifteen germplasm lines for their resistance/tolerance to pod borer under natural infestation in pesticide-free open field. Considering the yield potential ICP-13201, ICP-13214 and ICP-13212 showed higher yield potential than other genotypes. Considering the lower susceptibility to *H. armigera* and higher yield potential ICP-13201 was found to be the best.

Anitha Kumari et al. (2010[b]) evaluated a set of twelve diverse genotypes for resistance to *H. armigera* for two years over four plantings under natural infestation. The genotypes ICPL 187-1, ICP 7203-1, ICPL 98008, T 21, ICP 7035, and ICPL 332 exhibited moderate levels of resistance to *H. armigera* across planting dates, although there were a few exceptions. ICPL 187-1, ICP 7203-1, ICPL 84060, ICPL 87119 and ICPL 332 also showed better grain yield potential than the susceptible checks, ICPL 87 and ICPL 87091. Grain yield of most of the genotypes under *H. armigera* infestation was also unstable, except that of ICPL 87119, ICP 7035 and ICPL 332.

### 2.2 Mechanisms of resistance to *H.armigera* in pigeonpea

#### 2.2.1 Antixenosis/ nonpreference for oviposition

The term antixenosis was proposed by Kogan and Ortman (1978) to replace the term non-preference which was proposed, earlier by Painter (1951). Antixenosis may be due to morphological or chemical

factors that affect the insect behavior adversely, resulting in the selection of an alternative host plant. The morphological characters involved with insect resistace are colour, shape, succulence, toughness, spines and trichomes of the host plant. Considering the ovipositional preference by the pest and characteristics of the various genotypes following available literatures have been reviewed.

Pearson and Darling (1958) observed that oviposition in *H.armigera* usually starts some hours after dusk, initially alternating with feeding, and later becoming the predominant activity soon after midnight.

The selection of the oviposition site by the adult insects is often most crucial for the survival of its offspring, as neonate larvae are usually incapable of moving very far for food. However, *H. armigera* can oviposit freely in captivity even on unsuitable substrates (Eherlich and Raven, 1964).

Millar and Strickler (1984) studied the complete chain of sequences, which culminate in oviposition, which were guided by multiple sensory cues like visual, particularly color, shape, plant volatiles and surface texture.

Zalucki et al. (1986) reported that preference of moths to oviposit on plants during the reproductive growth stage could be due to an increase in chemical attractiveness of the crop.

Topper (1987) noticed the rapid increase in egg laying of *H.armigera* in the dark period succeeding dusk.

Courtney and Kibota (1990) suggested that the host selection behavior of an insect depends on its physiological state including age, feeding status, mated status and load. The preference for particular host *H.armigera* is shown by laying more eggs. Presence of certain physiological cues in the host plants is responsible for exhibiting the preference by the insect.

Schoonhoven (1990) reported that preference of *H. armigera* to particular genotype, shown by laying more eggs, indicates the presence of physiological cues which trigger oviposition. These cues may visual as well as chemical.

Fitt (1991) reported that female moths used various physical and chemical cues during oviposition to determine the susceptibility of the host plant such as hairy or rough surfaces were preferred for egg laying by *H. armigera*.

Pigeonpea genotypes showing resistance to *H.armigera* under field conditions exhibited oviposition non-preference under laboratory conditions also (ICRISAT, 1991).

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 significantly higher in ICPL-270 compared with LRG-30, ICPL-332 and ICPL-84060. The larval population 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.

Sison et al. (1993) Conducted oviposition preference experiments under no-choice and multi-choice conditions with six 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, 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).

King (1994) reported that on pigeonpea, most of the eggs were laid on flowers and flower buds, and sparingly on the leaves mostly during the vegetative phase of host. In contrast to other hosts, oviposition on chickpea declines with the onset of flowering.

Hardwick (1995) studied that moths are highly selective in their choice of host plant, and suitable conditions of development. The number of eggs laid on a particular genotype was largely the function of physio-chemical cues perceived by the females, as the females are highly selective in the of host plants regarding their suitability for survival and development of larvae. The *H. armigera* female shows distinct preference for different host plants.

Hartlieb and Rembold (1996) reported that female *H.armigera* moths were highly attracted by steam distillate from pigeonpea plants. A mixture of six compounds, all sesquiterpenes (ß-caryophyllene, a-humulene, a-guajene, a-muurolene, y-muurolene and a-blunesene) mixed in the proportions as found in the steam distillate , elicited the same behavioral responses. compound present in pigeonpea. In addition, sesquiterpenes mixture act as an oviposition stimulant.

Mustapha and Zalucki (1998) reported the physiological state of the *H. armigera* females influences the host plant specificity and propensity for oviposition. They 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 greatly influences her host plant specificity and propensity to oviposition motivation. Distribution of the eggs by the mated females peaked shortly after mating and declined steadily thereafter until death.

Romies et al. (1999) reported that in pigeonpea, more than 80 per cent eggs were laid on calyx and pods. Three factors were responsible for the ovipositional preference, which included long and sticky trichomes exudates provides a secure substrate for the eggs and the calyx and pods provides an 'enemy-free space' for eggs and larvae.

Laxmipathi (2000) studied the influence of flower color on oviposition preference by *H. armigera* in pigeonpea and it was found that yellow colored flowers were preferred over pink flowers.

Sharma et al. (2001) recorded that *A. cajanifolia* and *A. cericeus*, *Rhycosia bracteata* and *A. albicans* were 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 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.

Anitha kumari et al. (2006) studied the antixenosis mechanism of resistance to *H. armigera* in a diverse arrey of pigeonpea genotypes under no choice, dual-choice and multi-choice conditions.

Antixenosis for oviposition was observed in case of ICPL-187-1, ICP-7203-1, ICPL-88039, T-21, ICPL-84060 and ICPL-332 under no-choice, dual-choice and multi-choice conditions. The susceptible check, ICPL-87 was highly preferred for oviposition under no-,dual- and multi-choice conditions Antixenosis for oviposition observed under laboratory conditions is also exhibited under conditions in the field.

Sujana et al. (2008) evaluated a diverse array of wild relatives of pigeonpea for oviposition non-preference and antibiosis components of resistance to *H. armigera*. The accessions ICPW-1 (*Cajnus acutifolius*), ICPW-13 and 14 (*C. albicans*), ICPW-159 and 160 (*C. sericeus*), ICPW-68 (*C. platycarpus*), ICPW-83, 90, 94, 125, 137, 141 and 280 (*C. scarabaeoides*), ICPW-207 (*Paracalyx scariosa*) and ICPW-210 (*Rhynchosia aurea*) showed high levels of antixenosis for oviposition under no-choice, dual-choice and multi-choice conditions.

Sharma et al. (2009) observed that among the wild relatives, oviposition non-preference was an important component of resistance in *C. scarabaeoides* while heavy egg-laying was recorded on *C. cajanifolius* (ICPW-28) and *Rhynchosia bracteata* (ICPW-214). Accessions belonging to *Rhynchosia aurea, C. scarabaeoides, Cajnus acutifolius, Flemingia bracteata and C. sericeus* showed high level of resistance to *H. armigera* while *C. cajanifolius* were as susceptible to *H. armigera* as the cultivated pigeonpea. Among the cultivated pigeonpea genotypes, ICPL-332 (the resistant check) was consistently less damaged than the susceptible check, ICPL-87.

Muhammad Afzal et al. (2012) studied oviposition responses of *H. armigera* in different genotypes of cotton in relation to plant characters viz., trichome density, trichome length and gossypol glands from midrib, veins and leaf lamina , moisture contents and thickness of leaf lamina. Significant variations were observed in oviposition. All the characters were negatively correlated with the oviposition, except trichome length on leaf lamina. Trichome density on leaf lamina, thickness of leaf lamina and gossypol glands on leaf lamina had significant but negative correlation.

### 2.2.2 Antibiosis mechanism of resistance to *H.armigera*

Antibiosis is one of the important resistance mechanisms in plants to insects described by Painter (1951). Antibiosis includes the adverse effects of physico-chemical characteristics of the plants on the biology of an insect attempting to use that plant as a host. Both chemical and morphological factors mediate antibiosis. The effects of these factors may be acute, often affecting eggs and young larvae. The chronic effects of antibiosis are also expressed in terms of weight and size of insects, sex ratio and proportion of insects entering into diapauses (Dhandapani and Balasubramanian, 1980).

Lateef et al. (1981) reported that larvae of *H. armigera* fed on *Cajanus scarabaeoides* and *C. sericeus* were smaller, weighed less and took a longer time to develop than those pigeonpea. Resistance in these species was attributed to antibiosis, but several other morphological features were also involved.

*H. armigera* larvae fed on artificial diets containing powder from ground seeds of resistant and susceptible pigeonpea genotypes indicated that seed coat from brown coloured seed had a antibiotic effect on the larvae. Most larvae that are fed on the diets containing 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).

Dodia and Patel (1994) screened eleven pigeonpea genotypes using third instar larvae of *H. armigera* showed significant gain in larval, pupal and adult weights in genotypes having lower level of tripsin inhibitors. A significant decline in the larval and pupal weights and longer duration in both the stages were observed for larvae fed on developing pods of resistant varieties, ICPL-270 and ICPI-84060 as compared to fed on the susceptible variety BDN-2.

Sison and Shanower (1994) observed that the larvae of *H.armigera* reared on ICPL-86012 had the lowest larval weight and longest larval period whereas, those reared on ICPL-86005 had the lowest pupal weight and longer pupal period among the short-duration genotypes of pigeonpea. Larvae reared on ICPL-87 had the shortest larval time, the

highest larval and pupal weights and longest adult lifespan. Larval and pupal weights were significantly higher, larval developmental period significantly shorter and adult lifespan significantly longer when larvae were reared on pods compared with flowers or leaves.

Dodia et al. (1996) found that larval and pupal development period and pupal length were adversely affected when fed on flowers of wild relatives of pigeonpea such as *C. scarabaeoides*, *C. cajanifolius* and *C. sericus* and a few larvae survived to maturity. Growth index and fecundity were also adversely affected in the larvae reared on wild species and their $F_1$. The adult emerging from larvae reared on wild species were smaller than the adults, which emerged from cultivated pigeonpea.

Shanower et al. (1997) revealed that larval mortality and prolongation of larval period were the main componants of resistance to *H.armigera* in the pigeonpea wild relative, *Cajanus scarabaeoides*. Flower buds, mature and immature pods, seeds and dehulled split cotyledons of two resistant (ICPL-87088 and ICPL84060) and one susceptible (ICP-1691) pigeonpea (*Cajanus cajan*) cultivars fed to *H. armigera* larvae previously starved for 24 h, to determine the involvement of antibiosis in the resistance mechanisms of ICPL-87088 and ICPL-84060 against pod borer. Weight change in the larvae was measured for 9-12 days, in general, no significant differences were observed in the larval weight gain by *H. armigera* feeding on different plant parts.

Green et al. (2002) studied the feeding and food selection behavior of different instars of the pod borer in response to choices between the cultivated and wild species of *Cajanus*. First and second instars on cultivated variety of *C. cajan* in preference to *C. scarabaeoides*, 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 vulnerable to desiccation and predation. Later instars (third and fifth) prefer to feed on pods due to changes in nutritional requirements across the instars. Older larvae of Lepidoptera had increased appetitive behavior and need more protein.

Sujana et al. (2008) evaluated wild relatives of pigeonpea for antibiosis components of resistance to *H. armigera*. High levels of

antibiosis were observed when the larvae were reared on leaves and /or pods of *C. acutifolius* (ICPW-1), *C. cajanifolius* (ICPW-29), *C. sericeus* (ICPW-160), *P. scariosa* (ICPW-207), *C. scarabaeoides* and *C. albicans* . Lyophilized leaf or pod powder incorporated into the artificial diet used to assess antibiosis to *H. armigera* and high levels of antibiosis to *H. armigera* were observed in diet with leaf and /or powder of some of the accessions of *C. acutifolius, C. sericeus, C. scarabaeoides, P. scariosa, C. lineatus, C. platycarpus,* and *R. aurea*. Post-embryonic development period was prolonged in insects reared on leaves and pods of wild relatives.

Anitha Kumari et al. (2010[a]) standardized a bioassay involving incorporation of lyophilized leaves or pods into the artificial diet to assess antibiosis component of resistance to *H. armigera*. Incorporation of 10g of lyophilized leaves or pods into the artificial diet (300 ml) of diet resulted in maximum differences in survival and development of *H. armigera* larvae on the resistant (ICPL-332) and susceptible (ICPL-87) genotypes. Reduced larval and pupal weight, and prolongation of larval and pupal development periods were observed in insects reared on intact leaves or pods of ICPL-332, ICPL-84060, ICP-7035, ICPL-88039 and T-21. Similar effects were also observed in larvae reared on artificial diet impregnated with lyophilized leaves or pods of ICPL-332, ICPL-84060, ICP-7035, ICPL-187-1, ICPL-88039 and ICP-7203-1. Larval and pupal periods, pupal weight, and pupation and adult emergence were positively correlated between the insects reared on fresh leaves or pods, and on artificial diets impregnated with lyophilized leaves or pods.

Sujana et al. (2012) studied the feeding behavior of pod borer *H. armigera* in relation to biochemical characteristics of the pod surface exudates in a diverse array of germplasm. Feeding by *H. armigera* larvae was significantly lower on unwashed or water, methanol or hexane washed pods of *Cajanus serceus, C. scarabuides, Flemingia bracteata, F. stricta and Rhynachoisa aurrea* than those of *C. acutifolius, C. albicaus, C. cajanifolius, C. lineatus, D ferruginea, P.scariosa, R. bracteata* and cultivated pigeonpea *C. cajan* genotypes ICPL-87 and ICPL-332. The methanol washed pods of wild relatives were less preferred for feeding by the *H. armigera* larvae than the unwashed pods, but the hexane washed

pods were preferred more than the unwashed pods. The result suggested that methanol extracted the phagostimulants from the pod surface, while hexane removed the antifeedants.

**2.2.3 Tolerance**

The ability of a plant to withstand or recover from the damage caused by insect abundance equivalent to that required to damage a susceptible cultivars is termed as 'Tolerance Mechanism of Resistance'. The expression of tolerance is determined by inherent genetic capability to outgrow an insect infestation or to recover and add new plant growth after the recovery from insect damage.

Tingey (1981) reported that effect 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 plant prevent the evolution of new biotypes, and also help in maintaining the populations of natural enemies. Development of new biotypes capable of feeding on resistant cultivars with antixenotic or antibiotic mechanisms of resistance can be delayed or minimized by utilizing tolerance as a polygenic resistance.

Bhatnagar et al. (1983) reported that activity of natural enemy on *H. armigera* in pigeonpea is quite low as compared to other crops such as sorghum.

Lateef (1985) reported that the levels of resistance to *H.armigera* in germplasm accessions were low to moderate. This has necessitated the need for selecting genotypes with greater ability to tolerate or recover from the pod damage.

Srivastava and Srivastava (1986) reported that the extent of damage during the podding stage can be reduced by selecting genotypes that flowers and mature before or after peak abundence of *H.armigera* and suffer low damage than those flowering during the periods of greatest insect abundence.

Patel and Patel (1990) screened 13 early and 13 midlate maturing varieties of pigeonpea against *H.armigera* and other pigeonpea

pests. None of the entry was completely free from the infestation of *H.armigera*.

Lateef and Pimbert (1990) reported that among the medium duration genotype most of the genotypes had intermediate growth habitat, and genotypes ICP- 909, PPE- 45-2, ICP- 1811- EB, ICP- 1903- E, (ICPL-332) and ICP- 10466- E3 have shown less susceptibility to pod borer.

Raut et al. (1993) conducted field screening of pigeonpea germplasm against pod borer complex. They observed entry H-84-14 had lowest grain infestation. Whereas,maximum damage was recorded in ICPL-317. The CORG-13, H-84-14, CO-5, ICPH-8, MTH-6, BON-33 and MTH-66 gave higher yield than the other entries. The total loss in grain yield varied from 8.68 to 54.84 per cent.

Mali and Patil (1994) conducted field screening of pigeonpea varieties against pod borers. They observed T-21 as least infested by pod borer complex.

Patel et al. (1994) studied field screening of pigeonpea genotypes against pod borer and podfly. They found among seven genotypes, GAUT-82-90 was the least susceptible genotype to all three insect pests, i.e. *H. armigera* and other pest with the highest yield potentials.

Minja et al. (1999) conducted field trial which have shown tolerance to pod borer (*Helicoperva armigera*) and pod fly damage at ICRISAT, Patancheru, India, were also tested in the field at Kabete and Kiboka, Kenya, and compared with five local cultivars. Pod borer damaged seeds from all genotypes. The results indicated that although some genotypes showed tolerance to pod borer and pod fly damage; they were highly susceptible to pod sucking bugs, suggesting that such tolerance is not transferable to other insect groups.

**2.3.1 Bio- physical basis of resistance**

Trichomes are epidermal appendages of diverse form and structure present on the leaf, stem, flower, and pod surfaces of many plant types. The most common morphological resistance mechanism is presence of trichomes. The role of trichomes as an insect defense mechanism has been studied by Levin (1973).

Bisen and Sheldrake (1981) reported three types of trichomes in *C. Cajan* viz., Simple nonglandular, yellow glandular sacs and tubular trichomes and suggested that glandular trichomes are source of the characteristic fragrance of pigeonpea.

Southwood (1986) reported that variation in forms and functions of trichomes within the same species was the basis of plant resistance to insect attack. Trichomes may either glandular (secrete or contain chemicals) or non-glandular (do not secrete or contain chemicals).

David and Easwaramoorthy (1988) reported that the chemicals in and on the glandular trichomes may be either toxic or may impede the insects ability to move, feed and or survive. The volume of the exudates secretion varies with weather, time of day and plant age and they play an important role in host selection process of insect herbivore. Trichome types, their orientation, density and length influence host plant resistance/ susceptibility to insect pests.

John Peter (1995) observed that trichome density exhibited a negative impact on larval survival, growth and development. Behavioral study indicated that the neonate larvae were unable to reach the feeding site in time, which led to larval desiccation.

Hartlieb and Rembold (1996) suggested that glandular-secretions from trichomes in pigeonpea act as attractants to the adults of *H. armigera*.

Shanower et al. (1997) observed five types of trichomes viz; Type A, Type B, Type C, Type D and type E on pods of *Cajanus cajan* species and reported their importance in mechanism of resistance against *H. armigera*. The dense covering of trichomes on pods of *C. Scarabaeoides* was responsible for low neonate survival compared with *C. Cajan* or *C. platycarpus*. The nongladular 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 time to develop than the larvae other two *Cajanus* sp. 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.

Romeis et al. (1999) reported dense nonglandular trichomes on pods of wild pigeonpea act as a physical barrier to young *H. armigera* larvae, while the glandular trichomes act as attractants to adult moths.

Valverde et al (2001) reported that nonglandular trichomes usually have hooked tips, which trap the insect, impede the insect activity by holding the insect and disallowing a contact with foliar surface, leading to starvation. Trichomes affect the physiology of insect by interfering with its digestion.

Green et al. (2003) reported the phagostiulant/ antifeedant activity of glandular trichomal secretions towards *H. armigera* larvae.

Rupakula Aruna et al. (2005) observed that resistance to pod borer and trichomes associated with it (low density of type A trichome and high density of type C) were governed individually by dominant alleles of single genes.

Sharma et al. (2009) reported that glandular trichomes (type A) on the calyxes and pods were associated with susceptibility to *H. armigera*, while the non-glandular trichomes (trichome type C and D) were associated with resistance to this insect.

**2.3.2 Biochemical bases of resistance**

Schoonhoven (1968) reported that plants are known to produce certain chemical compounds, in different quantities and proportions, which affect the behavior of phytophagus insects in various ways these compounds can be attractants (oviposition and feeding stimulants) or repellants (oviposition and feeding deterrents) or antibiotic (reduced survival, growth and development).

Singh and Jotwani (1980) reported significant positive correlation between total sugar and pod borer damage.

Khurana and Verma (1983) observed that total sugar content showed a significant and positive correlation coefficient with pod borer damage.

Salunkhe et al. (1986) reported that the protein content of commonly grown pigeonpea cultivars ranges between 17.9 to 24.3 g/100g for whole grain and between 21.1 to 28.1 g/100g for split seeds.

Martin et al (1987) indicated that there is little evidence to suggest that condensed tannins inhibit digestion in insects, but the adverse effects of condensed tannins might be due to their role as feeding deterrents.

Butler (1988) reported that phenolic compounds in sorghum caryopsis improve resistance to insects, fungi and other pathogens.

Fitt (1989) reported that *H. armigera* preferred high protein due to which reproductive and growing plant parts contributes to serious losses in crop yield.

Mathews (1989) reported that among the pod borers, *Helicoverpa armigera* (Huber) (Lepidoptera:Noctuidae), is the most devastating pest.

Singh et al. (1990) carried out field trial to determine protein content of wild species of pigeonpea. The result showed that wild relatives of pigeonpea were promising source of high protein and several high-protein genotypes with protein content as high as 32.5 per cent.

Wu and Li (1990) stated that the nutritional requirement of early instars was probably higher and need more qualitative food. It was observed that increase in dietary from 7 to 13 per cent significantly shortened the larval stage. The result showed that a dietary carbohydrate : protein ratio of 15 : 2.6 was most suitable for maximum population growth. It indicated that both carbohydrate and protein concentration and their ratio influence the population dynamics of *H. armigera*.

Annadurai et al. (1990) suggested that the relative concentrations of various phenols play an important role in determining 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.

Guerra et al. (1990) reported that addition of phenolic compounds to the diet increased larval mortality and time required for the

Romeis et al. (1999) reported that polar chemicals on plant surface also stimulate oviposition behaviour of *H. armigera*. The acetone extracts from the pod surface of *C. cajan* stimulated the feeding of third instar larvae of *H. armigera*.

Verulkar and Singh (2000) studied mechanism of resistance to pod borer in pigeonpea using Pant A-3 and wild species *C. scarabaeoides*. HPLC technique was used to study the phenolic contents in the parents, F1 and F2 plants. Vanillin acid showed a high correlation with pod borer resistance.

Simmonds and Stevenson (2001) isolated four isoflavonoids from wild relatives of chickpea and reported their antifeedant activity against *H. armigera* larvae. The isoflavonoids were tested in combinations and with chlorogenic acid; the combinations containing judaicin and maackiain were most active, and chlorogenic acid enhanced the antifeedant activity of all four isoflavonoids.

Green et al. (2002) reported that the lower concentrations of phytoalexin (phagostimulants) present in the pod surface extract of ICPL-87 favored the larval feeding, but at higher concentrations the compound deters feeding by the larvae. This indicates that it could be a useful character for deterring larvae from feeding on pods in field.

Sahoo and Patnaik (2003) studied the effect of biochemical on the pigeonpea pod borer (*H. armigera)* under field and laboratory conditions in Bhuvaneshwar, Orissa, India during 1994-97 cropping seasons on pigeonpea cultivars H-89-2, ICPL-83024, AS-46, T-21, AS-36, H-82-1, AKT-8811, ICPL-1, ICPL-87, and UPAS-120. The biochemical basis of resistance indicated that low amino acid and protein contents induced resistance in the pigeonpea cultivars against borers. The protein content was estimated at 6.5 to 8.9 per cent in the pod coats of H-89-2, ICPL-83024, AS-46, T-21, AS-36. The seed of these entries contained 16.1 to 18.2 per cent protein. They also reported that low sugar (2.91-3.44 per cent in pod coats and 2.86 to 3.51 per cent in seed) was observed in resistant cultivars. On other hand, high sugar (3.66 to 4.92 per cent in seed coats; 3.64 to 4.82 per cent in seeds) was reported in ICPL-1 variety of pigeonpea.

Green et al. (2003) reported that 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-methyether 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 quercetin and higher concentrations of iso- querecetene than the cultivated variety characterized pod surface extracts of pod borer resistant cutivars. In addition, the stilbene to querecetene-3-methyl ether was greater in pod borer resistant cultivars.

Kranthi et al. (2003) reported that semilooper *Anomis flava* Fab., feeding on in vivo plants induced an increased concentration of quercetin, which caused growth inhibition of larvae of *H. armigera*.

Upasani et al. (2003) noted the role of flavonoids in *Ricinus communis* L. as insecticidal and antimicrobial agents against the bruchid, *Callosobruchus chinensis* L.

Mallikarjuna et al. (2004) demonstrated a combined effect of all the three flavonoids (quercetin, chlorogenic acid and rutin) in lines derived from wild *Arachis* spp. Various developmental stages of larval, pupal and moth deformities, thus leading to significant mortalities. The results from this study indicate that the presence of three flavonoids may play an important role for resistance to *H. armigera* and *S. litura* not only in groundnut but also in pigeonpea.

Onyilagha et al. (2004) investigated thirty seven flavonoid compounds for their effect on feeding choice with *Mamestra configurata*. Unsubstituted flavones and flavanone were the strongest feeding deterrents in choice bioassay. In a no-choice bioassay, flavones reduced both larval weight as well as larval and pupal development time.

Rizwana Banu et al (2007[a]) identified three phenols (Benzoic acid, Paranitro phenol and Orcinol) in different generations of pigeonpea. Concentrations of phenols were higher in tolerant cultivars (ICP-13201) than susceptible (CO-5). While comparing three phenols amount of orcinol was higher than that of other two phenols.

Sharma et al. (2009) reported that expression of resistance to *H. armigera* in pigeonpea genotypes is associated with low amounts of sugar and high amounts of condensed tannins and polyphenols.

Jadhav et al. (2012) studied the effect of three flavonoids namely chlorogenic acid, querecetin and rutin at varying concentrations on growth, development and mortality of larvae of *H. armigera* in artificial diet. Rutin caused significant effect on the inhibition of *H. armigera* larvae in higher concentrations, larvae spent 30-51 days excess in III–V instar which had negative impact on growth because of cessation of feeding. Healthy *H. armigera* moth emergence was common in chlorogenic acid and quercetin, but the moths did not produce any progeny.

Jagtap et al. (2012) reported that resistance to *H. armigera* was positively and significantly correlated with gain in larval weight and total sugar contents and significantly negatively correlated with total tannin content and total phenol content. Gain in larval weight was negatively and significantly correlated with total tannin, total sugar content, total phenol content and pod length. The correlations of total phenol content and total tannin content with total sugar content were also negative and significant. The correlations were significantly positive for pod length and total phenol content with total tannin content; pod wall thickness and petiole length with total sugar content. Thus, lower total sugar content, higher total tannin content and total phenol content with longer pods are good indicators of resistance to *H. armigera*.

CHAPTER III

# MATERIAL AND METHODS

The material used and the methods adopted for the present investigations are presented here in appropriate headings and subheadings.

## 3.1 Screening of pigeonpea genotypes against *Helicoverpa armigera* (Hubner) under field conditions.

Field experiments were conducted to study the reaction of twenty four pigeonpea genotypes including ICPL– 332 as resistant check, and ICPL–87 as susceptible check against *H. armigera* (Hubner). The experimental details for conducting these studies are given in the following pages.

### 3.1.1 Experimental Site

The present investigation was conducted at Department of Agril. Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season of 2011-2012 and 2012-13.The site selected was uniform with medium black cotton soil having fairly good drainage.

### 3.1.2 Geographical location and Weather Conditions

Akola is situated in the subtropical region at the Latitude 20.22$^0$ N, Longitude 77.02$^0$E at 307.415 M.S.L. with 818.6 mm normal rainfall. During *kharif* 2011 field screening only 468.8 mm rainfall was received in 29 rainy days from 26$^{th}$ meteorological week of 2011 to 8$^{th}$ meteorological week of 2012 and during *kharif* 2012 field screening 732.1 mm rainfall was received in 44 rainy days between 26$^{th}$ meteorological week of 2012 to 8$^{th}$ meteorological week of 2013. The mean temperature was fluctuated from 26.5$^0$C to 35.0$^0$C with relative humidity from 55-94% during *kharif* 2011 whereas; in *kharif* 2012 temperature was from 26.5$^0$C to 34$^0$C with relative humidity from 62-94%. The detail meteorological data are provided in Appendix - I and II.

### 3.1.3 Experimental details

#### 3.1.3.1 Field Screening

Field experiments were laid out (Plate 1 and Fig.1.) with twenty four treatments (genotypes) replicated thrice as adopted by Ujagir et al. (2005) the details of the experiment are as given below.

| | | |
|---|---|---|
| 1. | Design of experiment | Randomized Block Design |
| 2. | Treatments | Twenty four |
| 3. | Replications | Three |
| 4. | Border space between two replications | 1m |
| 5. | No of rows per genotypes | 4 |
| 6. | No of plants per genotypes | 48 |
| 7. | Spacing : | |
| a) | Row to row | 60 cm. |
| b) | Plant to plant | 15 cm. |
| 8. | Date of sowing | |
| a) | *Kharif* 2011 | 12.07.2011 |
| b) | *Kharif* 2012 | 09.07.2012 |
| 9. | Fertilizer | 100:60:40 NPK |
| 10. | Date of Harvesting | |
| a) | *Kharif* 2011 | 30/01/2012 |
| b) | *Kharif* 2012 | 5/02/2013 |

#### 3.1.3.2 Treatment details

| Treatments | Name of genotypes | Source |
|---|---|---|
| $T_1$ | ICPL-20139 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_2$ | ICPL-20118 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_3$ | ICPL-99004 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_4$ | ICP-990016 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_5$ | ENT-11 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_6$ | ICP-10531 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_7$ | ICP-13198 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_8$ | ICP-HRL-4978-5 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_9$ | ICP-HRL-4979-2 | ICRISAT Screening Nursery Patancheru (AP). |


Fig. 1. Plan of layout


Plate 1. Field view of Experimental Plot

| | | |
|---|---|---|
| $T_{10}$ | ICP-HRL-4985-1 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{11}$ | ICP-HRL-4985-10 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{12}$ | ICP-HRL-4989-7 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{13}$ | ICPL-20062 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{14}$ | ICPL-332 (R) | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{15}$ | ICPL-909 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{16}$ | ICPL-97253 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{17}$ | PPE-45-2 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{18}$ | ICPL-87 (S) | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{19}$ | ICPL-87119 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{20}$ | PKV-TARA | Pulses Research Unit Dr. PDKV , Akola |
| $T_{21}$ | AKT-8811 | Pulses Research Unit Dr. PDKV , Akola |
| $T_{22}$ | BSMR-736 | Pulses Research Unit Badnapur, MAU Parbhani |
| $T_{23}$ | ICPH-2671 | ICRISAT Screening Nursery Patancheru (AP). |
| $T_{24}$ | ICPH-2740 | ICRISAT Screening Nursery Patancheru (AP). |

R = Resistant S = Susceptible

**3.1.3.3 Crop condition and package of practices**

After sowing, intercultural operations as well as fertilizer applications were done as per university recommendations. Due care was taken to maintain proper growth of the crop. No pesticidal spraying was applied.

**3.1.4 Recording observations**

**3.1.4.1 Screening of pigeonpea genotypes for resistance under field conditions**

In all, twenty four genotypes of pigeonpea including two cultivars (ICPL- 332 as resistant check, and ICPL-87 as susceptible check) were screened in the field condition to evaluate their relative resistance/susceptibility to *H. armigera* (Hubner). An experiment was planned in such a way that the genotypes were exposed to the peak abundance of *H. armigera* (Hubner). Data on oviposition by *H. armigera* females was recorded. For this purpose a 40 cm portion of inflorescence was marked at the pre flowering stage with a tags. Such five plants were tagged in each plot.

**3.1.4.2 Egg and larval count**

Observation, on number of eggs and larvae were recorded weekly per plant after tagging and presented as total number of eggs and larvae.

**3.1.4.3 Days to 50% flowering as agronomic trait**

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

**3.1.4.4 Days to maturity as agronomic trait**

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

**3.1.1.5 Per cent pod damage**

The total number of pods and the pods damaged by *H. armigera* were recorded at maturity in pods harvested from the tagged inflorescences from random five plants (Plate 2). *H. armigera* damage to pods was quantified by expressing the number of pod borer damaged pods as a percentage of total number of pods. Per cent pod damage was worked out and statistical analysis was done after suitable transformation of values.

**3.1.4.6 Insect damage score**

At harvest the crop was scored for *H. armigera* damage on a 1- 9 scale as given by ICRISAT (1992).

1 = < 10% pods damaged

2 = 10 to 20%

3 = 21 to 30%

4 = 31 to 40%

5 = 41 to 50%

6 = 51 to 60%

7 = 61 to 70%

8 = 71 to 80%

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

**3.1.4.7 100 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 were taken at random from each plant.

Plate 2. Damage caused by *H. armigera* on Pigeonpea

**3.1.4.8 Grain yield per plot and per hectare**

Total grain weight for the plot was calculated as plot yield. Then plot yield was extrapolated on a hectare basis.

**3.1.4.9 Trichome types and their density in 24 pigeonpea genotypes**

Trichomes are the most common morphological structure that play an important role in insect host plant interaction in pigeonpea and variation in their forms and functions quite often are associated with plant resistance in insect attack (Southwood, 1986). Hence the study was carried out to identify different types of trichomes and their density in all 24 different pigeonpea genotypes tested. The presence of trichomes on pods and calyxes 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 preservative (Acetic acid : absolute alcohol :: 1:3 ) and examined under a Nikon-i-10 compound microscope equipped with camera at a magnification of 40 X with an ocular measuring grid at different microscopic field and trichome density was averaged out.

**3.2 Mechanism of host plant resistance**

Painter (1951) categorized the insect resistance mechanism in host plants into three categories

a) Non-preference/Antixenosis
b) Antibiosis
c) Tolerance

**3.2.1 Mass culture**

The culture of *H. armigera* was obtained from the laboratory culture maintained at Laboratory of Department of Entomology Dr. PDKV Akola, India. The lab culture was regularly supplemented with field collected larvae (Plate 3). The larvae were reared on the chickpea based diet (Armes et al., 1992) at $27^{0}C \pm 2$. The adults were released in a cage with nappy liners hung inside for oviposition. The adults were supplied with 10% sucrose on absorbent cotton inside the cage. Eggs laid on the liners were sterilized with 1% sodium hypochloride solution. Neonates emerging from these eggs were transferred into the cups for rearing on artificial diet.

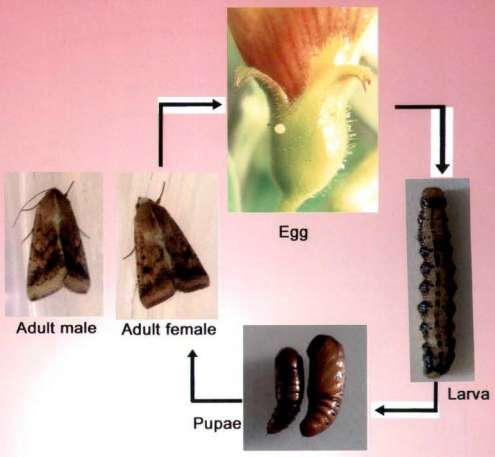



Plate 3. Life stages of *Helicoverpa armigera* (Hubner)

Adult mating and oviposition chamber

Larva feed on artificial diet

### 3.2.1.1 Preparation of artificial diet

For preparing the chickpea based diet for insect culture all the ingredients (Table-1) ingredient serial no. a to f and h were mixed thoroughly in water (g) in a large bowl of 2 L capacity by a mixer. The agar-agar was mixed with water (j) and heated in saucepan on a hot plate. The boiled agar-agar was mixed with other ingredients in a plastic bowl and stirred until an even consistency was obtained. This hot diet was later on poured into rearing trays so as to maintain 5mm thick layer and placed on a uniform surface. The diet in the trays was allowed to cool, and then the trays were wrapped in a polyethylene sheet to avoid contamination. As and when needed these multicellular trays were used for rearing the larvae. (Plate 4)

**Table 1. Chemical composition of diet for rearing *H.armigera* larvae as per Armes et al., (1992)**

| Sr. No | Ingredients | Quantity |
|---|---|---|
| a | Chickpea flour | 300.0 g |
| b | Ascorbic acid | 4.7 g |
| c | Methyl-P-hydroxybenzoate | 5.0 g |
| d | Sorbic acid | 3.0 g. |
| e | Auromycin powder | 11.5 g. |
| f | Vitamin stock solution | 10.00 ml |
| g | Water | 450.0 ml. |
| h | Yeast | 48.0 g |
| I | Agar | 17.3 g |
| j | Water ( for yeast/Agar) | 800.0 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 | Pyredoxine hydrochloride | 0.382 g |
| 6 | Folic acid | 0.382 g |
| 7 | D-Biotin | 0.305 g |
| 8 | Cyanocobal amine | 0.003 g |
| 9 | Water | 500.0 ml. |

### 3.2.2 Antixenosis/nonpreference Mechanism

Antixenosis for oviposition was studied under no choice, dual choice and multi choice conditions at ambient temperature in laboratory Department of Entomology Dr. PDKV Akola. The twigs with inflorescences used for studying antixenosis were procured from the respective genotypes specially grown in the experimental field for laboratory study purpose. Inflorescences were thoroughly examined with help of hand lens to remove eggs/larvae of the pests if any before experimentation. These mechanisms were studied as per methodology given by given by Sujana et al., (2008).

#### 3.2.2.1 Antixenosis for oviposition by *H. armigera* (No choice test)

One genotype was tested in a wooden cage (30x30x45cm) (Plate 5a). Five inflorescences (30 cm long) with few leaves were brought from the field, examined thoroughly with the help of hand lens to remove the eggs, larvae of the pests if any and ensured that there was no infestation just before experimentation and placed in a conical flask filled with water. Five pairs of two days old moths were released inside the cage. Moths were provided with sucrose solution in a cotton swab throughout 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 ants containers filled with water were kept under the four legs of the wooden table. Observations were recorded on the number of eggs laid on each inflorescences placed in a cage. Each experiment was replicated five times. Data were subjected to analysis of ANOVA in CRD.

#### 3.2.2.2 Antixenosis for oviposition by *H. armigera* (Dual-choice test)

Non preference for oviposition under dual choice test (Plate 5b) was studied by keeping a test variety with a susceptible check, ICPL-87 inside the wooden cage as described above. The inflorescences (30 cm long) were obtained from 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 provided with sucrose solution in a cotton swab. To avoid predation by ants containers filled with water were kept under the four legs of the wooden table. The experiment was replicated five times. Significance of difference between two test genotypes was compared by paired t-test at P=0.05.

a) No choice test

b) Dual choice test

c) Multi choice test

Plate 5. Relative oviposition preference of *Helicoverpa armigera* (Hubner) on different pigeonpea genotypes.

$$\text{Relative ovipositional preference} = \frac{\text{No of eggs laid on test variety} - \text{No of eggs laid on standard variety}}{\text{No of eggs laid on test variety} + \text{No of eggs laid on standard variety}} \times 100$$

**3.2.2.3 Antixenosis for oviposition by *H. armigera* (Multi choice test)**

Non preference for oviposition under multi choice test was studied by keeping the inflorescences all 24 varieties inside the wooden cage (110 x170 x60 cm) under room temperature (Plate 5c). Inflorescences of the test genotypes were brought from the field and kept in conical flask filled with water. The conical flasks (containing inflorescences) of all the genotypes were arranged inside the wooden cage in a completely randomized block design. Fifty 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 containers filled with water were kept under the four legs of the wooden table. Observations were recorded on the number of eggs laid on each genotypes. The experiment was replicated thrice.

**3.2.3 Antibiosis**

The antibiosis component of resistance was studied on flowers & pods under laboratory conditions. Data were recorded on:

1. Survival of larvae
2. Larval period
3. Weight of full grown larvae
4. Pupal period
5. Weight of pupae
6. Moth emergence
7. Sex ratio
8. Growth index
9. Fecundity per female
10. Adult longevity
11. Viability and hatching of eggs.

### 3.2.3.1 Rearing of *H. armigera* larvae on different pigeonpea genotypes

The larvae first feed on flowers and then on pods; therefore,under laboratory conditions, neonate *H. armigera* larvae were first 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 moistened filter paper attached to the lid. The petri plates were kept in laboratory at 27 $\pm$ 2°C and 45-65% RH. The experiment was conducted in completely randomized design with five replications and 12 larvae were released in each replication. The following observations were recorded during rearing on different cultivars:

**i) Per cent survival of larvae**

Number of larvae survived was counted at full grown stage before pupation out of 12 larvae released in each set of replication. Thus, percentage survival of larvae was worked out.

**ii) Larval period**

It is the average period in days from hatching to pupation. It was calculated by adding the time taken by each larva to pupate and dividing the same by the total number of larvae.

**iii) Weight of full grown larva.**

The full grown larva before pupation was straw - yellow to green with lateral brown strips and the head as well as prothoracic legs dark brown to black in color. Tubercles and spiracles of the larvae were also brown to black, giving them spotted appearance. Larvae become sluggish, wrinkled with suspended feeding and movement. The weight of such larvae was taken and averages were worked out.

**iv) Pupal period**

It is the average time taken from pupation to emergence of adults. It was calculated by adding the number of days taken by each pupa to become adult and dividing the some by total number of pupae.

**v) Weight of pupa**

The pre pupa was noticed as light green yellowish in color but later on it turned dark brown. The mature pupa was of obtect type with mahogany- brown color. The surface was smooth and it rounded both

anteriroly and posteriroly, with two tapering parallel spines at the posterior tip. The weights of such dark brown pupa were recorded and averages worked out.

**vi) Per cent moth emergence**

The total number of adults emerged from pupae were counted. The per cent emergence was calculated from number of larvae survived for pupation and number of moth emerged.

**vii) Sex ratio**

The sex ratio (female: male) was calculated. Female and male adults were identified individually by naked eyes on the basis of following characters.

**a) Male**

It measures on an average 17.65 $\pm$ 0.18 mm in length and 34.73 $\pm$ 0.59 mm in breadth across expanded wings. They are almost uniform pale cream in color.

**b) Female**

Females are larger and stouter than male and are dark grayish-brown color. It measures on an average 20.08 $\pm$ 0.38 mm in length and 40.93 $\pm$ 0.55 mm in breadth across expanded wings.

**viii) Growth index**

It was calculated by dividing the percentage of adult emerged by the average number of days taken by larvae to become adult.

**IX) Fecundity**

It was calculated by counting the total number of egg laid by all the female and dividing number of females laying eggs.

**X) Adult longevity**

It is the average time taken from emergence of adults to its death. It was calculated by adding the number of day adult lives after emergence and dividing the same by total number of adults.

**XI) Viability and hatching of eggs**

The total number of neonate larvae emerged from eggs was counted. The per cent hatchability was calculated from number of eggs laid by female and number of neonate larvae emerged from eggs.

### 3.2.4 Tolerance

At the time of pod maturity (before harvest) five plants were selected from each genotype and total number of healthy and damaged pods in 45 cm length inflorescence was counted and per cent pod damage was worked out. Some genotypes had higher infestation. However, even after having higher infestation it withstood the attack and yielded comparatively more; such genotypes that expressed tolerance mechanism were noted.

### 3.3 Biochemical basis of resistance

Biochemical constituents in all 24 genotypes were studied in order to know if any significant differences existed.

**Methods**

The uninfested healthy plants were used for collecting the samples. The analysis of flowers and pods were carried out in the Department of Agril. Entomology, Soil Science and Agril. Chemistry, Biotechnology Centre Dr. PDKV, Akola. Samples of healthy shoots were collected between 9-11 a.m. at clear sunlight. The leaves were clipped off remaining shoot portion was taken. All the samples (calyx and pods) were oven dried at 40°C. Each sample was powdered separately in grinding mill at Department of Soil Science and Agricultural Chemistry Dr. PDKV, Akola. Powder was sieved through 60 mesh size sieve. This powder was then used for analysis of crude protein, total sugars, total phenols, tannins and flavonoid contents and data were correlated with pod infestation for their significance.

**Chemical composition**

Biochemicals imparting resistance/ susceptibility in pigeonpea genotypes to *H. armigera* viz., crude protein, total sugars, total phenols, flavonoids were estimated on per cent basis according to standard procedure. All the estimation of biochemicals was followed as per standard methods given by AOAC (1975).

### 3.3.1 Crude protein

The said work was carried out in the Department of Soil Science and Agril. Chemistry, Dr. PDKV, Akola. The total protein was estimated by Micro-kjeldhal's Method.

**Reagents:**

**NaOH 40 per cent:** NaOH 400 gm was dissolved in one liter of distilled water.

**NaOH 0.02 N:** NaOH pellets of 900 mg were dissolved in distilled water and final volume was made to one liter.

**$H_2SO_4$ 0.002 N :** Concentrated sulphuric acid 0.56 ml was slowly added to 500 ml of distilled water and final volume was made to one liter.

**Methyl red indicator:** One gram methyl red indicator was dissolved in 100 ml of 90 per cent ethyl alcohol.

**Digestion:** Oven dried pigeonpea samples of 0.2 gm was digested by 5 ml of $H_2SO_4$, and 5 ml of $H_2O_2$. Then, the final volume was made to 100 ml.

**Distillation and titration**

Ten ml of above solution was transferred to distillation flask and 10 ml of 40 per cent NaOH solution was added. Ammonia evolved was collected in 10 ml of 0.002 N $H_2SO_4$ solution to which two or three drops of methyl red indicator was added and then titrated with 0.02 N NaOH solutions and the percentage of nitrogen was calculated. Protein content was calculated by multiplying nitrogen percentage by a factor of 6.25.

**3.3.2 Estimation of Total phenol**

Total phenol from pigeonpea calyx and pods was determined by the method of Bray and Thorpe (1954).

**Materials:** Alcohol extracted sample, pipettes, test tubes, water bath, and spectrophotometer.

**Reagents:** Folin Ciocalteu reagent 'ready to use' reagent (2.0 normal) of m/s Lobacheme was used, 20 per cent sodium carbonate and tannic acid solution.

**Method:**

One milliliter of calyx and pod extract was taken into a test tube using pipette. 1ml of folin Ciocalteu reagent followed by 2ml of $Na_2CO_3$ solution was added and the tubes shaken using automatic shaker. The mixture then heated in boiling water bath for exactly 1 minute. After boiling, solution was allowed to cool and diluted the blue solution to 100 ml

with distilled water and absorbance was measured at 650 nm in a spectrophotometer.

A blank containing the entire reagent was maintained to adjust the absorbance to zero. A standard graph was prepared by plotting absorbance v/s tannic acid concentration, with the help of this standards, per cent total phenol was calculated.

### 3.3.3 Estimation of Total soluble sugar

Total soluble sugar from calyx and pods of different pigeonpea genotypes was determined as per method given by Dubois et al. (1956).

**Reagents**

**80 % ethyl alcohol:** 800 ml of ethanol was mixed in water to make up to 1 liter of solution.

**5% phenol:** 5 gm of phenol dissolved in water to make volume up to 100 ml solution 96 per cent sulphuric acid

**Glucose standard**

**Method**

Dried pigeon pea calyx or pod samples of 500 mg were weighed; 25-30 ml of hot 80 % ethanol was added in vertex mixer and allowed to settle for 20-30 minutes. The settled material was then filtered into a beaker using Whatman No.41 filter paper. The obtained extract was kept in a hot water bath until the ethanol evaporates. About 10 ml water was added and dissolved content was transformed into 100 ml volumetric flask. The contents was washed 2-3 times and then added to volumetric flask by making it up to 100 ml with distilled water. One milliliter of aliquot from above content and 1 ml water as blank was taken into a test tube and 1 ml of 5 per cent phenol was added and then placed on shaker for shaking. Then 5 ml of 96 per cent sulphuric acid was added to it. Absorbance of golden yellow colour was measured at 490 nm against the blank. With different concentration i.e. 10, 20, 30, 40 and 50 mg of glucose standards was run and per cent total soluble sugar was calculated with the help of standard graph.

### 3.3.4 Estimation of tannins:

The amount of tannins present in flowers and pods of pigeonpea genotypes estimated by Vanillin-Hydrochloric acid method (Price et al., 1978). The following reagents were used in present study.

1. 8% HCl in methanol (v/v): 8 ml conc HCl in methanol and make upto 100 ml.
2. In methanol 1 mg of Vanillin was dissolved and final volume was made to 100ml.
3. Vanillin-Hydrochloric acid reagent: Equal volumes 1 and 2 were mixed before use.
4. 4% hydrochloric acid in methanol (v/v): 1 ml conc. HCl in the 96 ml methanol.
5. 1% hydrochloric acid in methanol (v/v): 1 ml conc. HCl in the 99 ml methanol.
6. Standard solutions: A stock solution was prepared by dissolving 1 mg of catechin in 1 ml of methanol.

From the defatted material, 100 mg is transferred to a centrifuge tube containing 2 ml of 1% acidic methanol, centrifuged for 10 min. and the aliquot is transferred to a 5 ml volumetric flask. This step was repeated by adding 1 ml of (1%) acidic methanol. The aliquot was transferred to the first extraction and the final volume of 4ml.

From the above extract 1ml was pipette out into a test tube and to it freshly prepared vanillin-HCl reagent was added slowly. An individual blank was prepared for each extract by adding 5ml of 4% HCl in methanol to 1ml aliquot. Finally the absorbance was recorded at 500nm against blank in a spectrophotometer.

Standard curve was prepared by plotting the average absorbance readings of the duplicate determinations of catechin concentrations. The catechin equivalents are calculated by using the formula

$$CE(\%) = \frac{\text{(mg catechin/ml)}}{\text{Vol. of extract taken}} \times \frac{\text{Volume made up}}{\text{wt. of sample}} \times 100$$

### 3.3.5 Estimation of Total flavonoids

Total flavonoids from pigeonpea calyx and pods were determined by aluminium chloride method.

**Materials:** Methanol extracted sample (1mg/ml), pipettes, test tubes, water bath, and spectrophotometer.

**Reagents:** 10% aluminium chloride solution, 1M potassium acetate, 1mg/ml stock solution prepared in methanol, distilled water.

100 µl of each plant extracts separately mixed with 1.5 ml of methanol. Then 0.1ml (100 µl) of 10% aluminium chloride, 100 µl of 1M potassium acetate and 2.8ml of distilled water was added. It was remained at room temperature for 30 minutes and then absorbance of the reaction mixture was measured at 415nm.

1mg/ml sock solution of quercetin was prepared in methanol. Than 1ml stock solution was diluted to make a volume up to 10ml with methanol. From this 0.1ml, 0.2ml, 0.4ml, 0.6ml, 0.8ml and 1ml were taken in different test tubes; volume of the test tube was made 1ml with distilled water. From these test tubes 100 µl were taken and standard curve of quercetin is prepared by plotting the average absorbance readings of the duplicate determinations of quercetin concentrations.

**Statistical Analysis**

Statistical analysis after appropriate transformation of data were undertaken as per Gomez and Gomez (1984). Data from the field experiments were analyzed by Randomized Block Design (RBD), while the data from the laboratory studies were analyzed by Completely Randomized Block Design (CRD). The data were analyzed with the help of computerized programme at computer cell, Dr. PDKV, Akola.

**Correlation studies**

The correlation studies were undertaken to find the correlation of the morphological as well as biochemical attributes with flower and pod infestations. The coefficient of correlation was worked out by equation

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \times \Sigma y^2}}$$

The per cent infestation was taken as dependent factors (x) and the morphological; biochemical attributes were taken as independent factor (y). to work out correlation coefficient , morphological factors of vegetative phage were taken as 'y' and pod infestation as 'x' and morphological factors, at bearing stage as 'y' and pod infestation taken as 'x'. In biochemical factors the different ingredients from the chemical compositions of the pods were taken 'y' and per cent infestations of pod were taken 'x', ingredients of chemical composition of pods were taken as 'y' and per cent infested pods was taken as 'x'.

CHAPTER IV

# RESULTS AND DISCUSSION

The present investigations entitled "Host plant resistance studies in pigeonpea genotypes against *Helicoverpa armigera* (Hubner)" were carried out in Department of Agril. Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.), India, wherein, various aspects pertaining to the field screening of 24 genotypes of pigeonpea under natural conditions against *Helicoverpa armigera* (Hubner)., mechanism of resistance viz. Antixenosis, antibiosis and tolerance; bases of resistance such as biochemical and morphological have been studied as per methodology and techniques described in the previous chapter.

The numerical data, thus obtained through observations on various aspects, were subjected to statistical analysis wherever necessary and complied mean data are tabulated in the following pages. Findings, so obtained, are presented and discussed under the light of previous literature aspect wise here under.

## 4.1 Field screening of pigeonpea genotypes for resistance against *Helicoverpa armigera* (Hubner).

Twenty four pigeonpea genotypes were screened in field under pesticide free conditions during *Kharif* seasons of 2011 and 2012. Infestation of *Helicoverpa armigera* (Hubner) was recorded and data thus obtained during the present study are described here under.

### 4.1.1 Morphological characters of different pigeonpea genotypes

Among the genotype tested, (Table-2) all have upright stem and semi determinate growth habit except susceptible check ICPL-87 which had determinate growth habit might be due to genetical reason. Stem colour of all genotypes was green. Plant height of the tested genotypes ranges from 80 cm to 172 cm. Shortest plant height was noticed in susceptible check ICPL-87 i.e 80 cm and longest in resistant check ICPL-332, (172cm). Plant height of rest of the genotypes ranged between 130 cm to 170 cm. Flower colour of most of the genotypes was yellow except ICPL-20118, ENT-11 and PPE-45-2 which had red colour flowers. Pod colour of most of the genotype was green with

Table 2. Morphological characters of different pigeonpea genotypes

| Genotypes | Growth habit | Plant height (cm) | Stem colour | Flower color | Pod colour | Pod hairiness | Leaf hairiness | Pod length (cm) |
|---|---|---|---|---|---|---|---|---|
| ICPL-20139 | Semi- determinate | 144 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.2 |
| ICPL-20118 | Semi- determinate | 136 | Green | Red | Green and purple strip | Pubescent | Glabrous | 6.5 |
| ICPL-99004 | Semi- determinate | 130 | Green | Yellow | Purple and green | Pubescent | Glabrous | 6.1 |
| ICP-990016 | Semi- determinate | 152 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.3 |
| ENT-11 | Semi- determinate | 169 | Green | Red | Green and purple strip | Pubescent | Glabrous | 7.7 |
| ICP-10531 | Semi- determinate | 155 | Green | Yellow | Green | Pubescent | Glabrous | 6.4 |
| ICP-13198 | Semi- determinate | 148 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.3 |
| ICPHRL-4978-5 | Semi- determinate | 138 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.2 |
| ICPHRL-4979-2 | Semi- determinate | 152 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.5 |
| ICPHRL-4985-1 | Semi- determinate | 140 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.4 |
| ICPHRL-4985-10 | Semi- determinate | 151 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.3 |
| ICPHRL-4989-7 | Semi- determinate | 144 | Green | Purple | Green and purple strip | Pubescent | Glabrous | 6.4 |
| ICPL-20062 | Semi- determinate | 170 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.4 |
| ICPL-332 (R) | Non-determinate | 172 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.5 |
| ICPL-909 | Semi- determinate | 140 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.3 |
| ICPL-97253 | Semi- determinate | 145 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.0 |
| ICPL-45-2 | Semi- determinate | 140 | Green | Red | Purple & green | Pubescent | Glabrous | 6.3 |
| ICPL-87 (S) | Determinate | 80 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 7.1 |
| ICPL-87119 | Semi- determinate | 168 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.5 |
| PKV-TARA | Semi- determinate | 159 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.3 |
| AKT-8811 | Semi-determinate | 136 | Green | Yellow | Purple and green | Pubescent | Glabrous | 6.3 |
| BSMR-736 | Semi- determinate | 161 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.1 |
| ICPH-2671 | Semi- determinate | 165 | Green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.4 |
| ICPH-2740 | Semi- determinate | 162 | green | Yellow | Green and purple strip | Pubescent | Glabrous | 6.5 |

R-Resistant check, S-Susceptible check.

purple strips. Pod colour of ICPL-99004 and PPE-45-2 was purple and green and genotype ICP-10531 had green colour pods. Pods of all genotypes were pubescent and leaves were glabrous. Pod length of tested genotypes range from 6.0cm to 7.7cm.Shortest pod length was noticed in ICPL-97253 (6.0 cm) and longest in ENT-11 (7.7 cm). Pod length of rest of the genotypes ranges between 6.1cm to 6.5cm

### 4.2.1 Agronomical traits of pigeonpea under screening

#### 4.2.1.1 Days to 50 per cent flowering and maturity

Among the genotypes tested, (Table-3, Fig.1)the days to 50 per cent flowering was the minimum in susceptible check ICPL-87 (82 days) followed by AKT-8811 (89 days), PPE-45-2, ICPL-20139, ICPL-99004 and ICP-10531 (101 days). Genotypes ICPL-20118, ICP-13198, ICPHRL-4979-2, ICPHRL-4985-1, ICPHRL-4989-7, ICPL-909, and ICPL-97253 recorded (102-104 days) for 50 per cent flowering. Remaining genotypes recorded (108-121 days) for 50 per cent flowering. The maximum number of days to 50 per cent flowering recorded in ENT-11. (121 days).

**Table 3. Agronomic traits of pigeonpea genotypes under screening (2011-12 and 2012-13)**

| Sr. No | Genotype | Days to 50% flowering | Days to maturity | 100-seed weight (g) |
|---|---|---|---|---|
| 1 | ICPL-20139 | 101 | 141 | 11.82 |
| 2 | ICPL-20118 | 104 | 146 | 11.02 |
| 3 | ICPL-99004 | 101 | 140 | 9.51 |
| 4 | ICP-990016 | 115 | 171 | 11.64 |
| 5 | ENT-11 | 121 | 183 | 14.95 |
| 6 | ICP-10531 | 101 | 139 | 9.71 |
| 7 | ICP-13198 | 104 | 143 | 8.99 |
| 8 | ICPHRL-4978-5 | 109 | 151 | 12.35 |
| 9 | ICPHRL-4979-2 | 103 | 143 | 9.85 |
| 10 | ICPHRL-4985-1 | 103 | 144 | 10.16 |
| 11 | ICPHRL-4985-10 | 109 | 152 | 10.88 |
| 12 | ICPHRL-4989-7 | 103 | 143 | 10.15 |
| 13 | ICPL-20062 | 118 | 176 | 9.89 |
| 14 | ICPL-332 (R) | 119 | 180 | 11.64 |
| 15 | ICPL-909 | 102 | 135 | 10.00 |
| 16 | ICPL-97253 | 102 | 134 | 11.67 |
| 17 | PPE-45-2 | 101 | 136 | 9.57 |
| 18 | ICPL-87 (S) | 82 | 119 | 10.92 |
| 19 | ICPL-87119 | 116 | 172 | 10.60 |
| 20 | PKV-TARA | 108 | 152 | 10.39 |
| 21 | AKT-8811 | 89 | 129 | 11.60 |
| 22 | BSMR-736 | 115 | 171 | 12.31 |
| 23 | ICPH-2671 | 116 | 172 | 10.63 |
| 24 | ICPH-2740 | 114 | 168 | 13.01 |

R-Resistant check, S-Susceptible check.

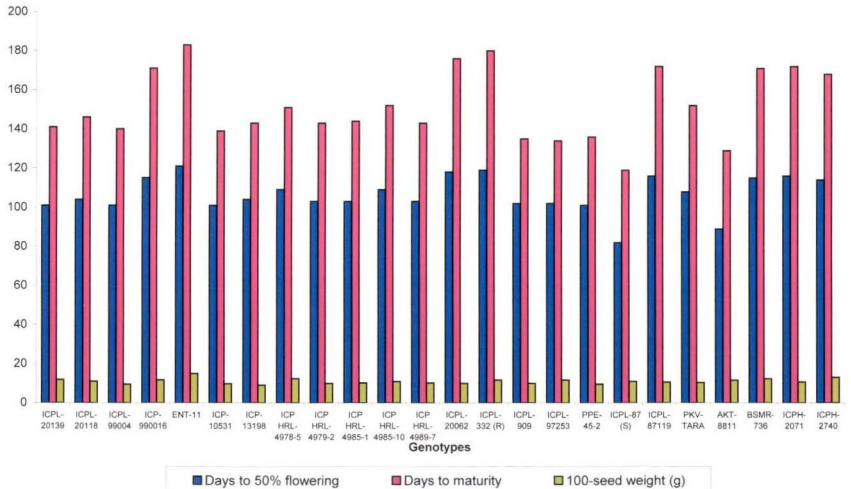



**Fig.2.Agronomic performance of pigeonpea genotypes under screening**

#### 4.2.1.2 Days to maturity

Among the genotypes tested (Table 3 and Fig.2) minimum days to maturity was for the susceptible check ICPL-87 (119 days). The maximum number of days to maturity was for ENT-11 (183 days).The rest of the genotypes took intermediate days to maturity.

#### 4.2.1.3 100 Seed weight

Among the genotypes tested, 100 seed weight was maximum for ENT-11 (14.95 g) followed by ICPH-2740 (13.01 g), ICPHRL-4978-5 (12.35 g) and BSMR-736 (12.31 g). Moderate 100 seed weight category genotype were ICPL-20139 (11.82 g) followed by ICPL-97253 (11.67 g), ICP-990016 and resistant check ICPL-332 (11.64 g), AKT-8811 (11.60 g), ICPL-20118 (11.02 g) and susceptible check ICPL-87 (10.92 g). The 100 seed weight was lowest for genotype ICP-13198 (8.99 g) followed by ICPL-99004 (9.51 g), PPE-45-2 (9.57 g) and ICPL-20062 (9.89 g). The 100 seed weight of remaining genotypes tested range between 10.88 g to 10 g. (Table 3, Fig.2).

### 4.2.2 Eggs and larvae on pigeonpea genotypes under field conditions

#### 4.2.2.1 *Kharif* 2011-12

Observations on egg and larval numbers were recorded on five inflorescences tagged at random in five plants in the center of each plot. Data on numbers of eggs and larvae were recorded in every week after tagging the inflorescences (Table –Appendix III). During *kharif* 2011, the lowest total number of eggs were recorded on ENT-11 (5) followed by resistant check ICPL-332 (6.6). The minimum number of larvae were also recorded on ENT-11 (1.8) followed by resistant check ICPL-332 (2.7). On the contrary the maximum number of eggs were recorded on susceptible check ICPL-87 (15.8) followed by ICPL-99004 (15.5), ICPHRL-4989-7 (15.4). While, the maximum number of larvae were horboured on susceptible check ICPL-87 (8.7) followed by BSMR-736 (8.3), ICPL-99004.

#### 4.2.2.2 *Kharif* 2012-13

During 2012 *kharif* season minimum number of eggs were recorded in ENT-11 (6.5) followed by ICPHRL-4979-2 (9.8), while minimum

number of larvae were recorded on ENT-11 (2.3) followed by resistant check ICPL-332 (4.1). Whereas, the maximum number of eggs were recorded on susceptible check ICPL-87 (18.2) followed by ICPL-99004 (17.7), (Table –Appendix-III).

It means that, ENT-11,resistant check ICPL-332 allowed to oviposit less eggs and could harbor only few larvae as compared to susceptible check ICPL-87(early group) and ICPL-99004 and BSMR-736 (susceptible in late group).

### 4.2.3 Pod damage rating

#### 4.2.3.1 *Kharif* 2011-12

Damage ratings based on the number of pods and the proportion of pods damaged by *H. armigera* indicate that during 2011 *kharif* season, lowest pod damage rating (DR) was recorded in ENT-11 (1.9) (Table-4, Fig.3) which was statistically at par with ICP-13189 (2.23), PPE-45-2 (2.6), ICP-10531 (2.77), ICPL-909 (2.83), ICP-990016 (2.9), resistant check ICPL-332 (2.93) and ICPHRL-4979-2 (3). Genotype ICPL-20026 recorded damage rating of (3.37) which was followed by ICPHRL-4985-10 (3.7), ICPL-20139 (3.73), ICPH-2740 and ICPH-2671 (3.83), PKV-TARA (3.87), ICPHRL-4985-1 (3.93) AKT-8811(3.97) and ICPL-87119 (4) in their order and were at par with each other. Highest damage rating was observed in susceptible check ICPL-87 (5.97) which was followed by BSMR-736 (5.9) and ICPHRL-4978-5 (4.93).

#### 4.2.3.2 *Kharif* 2012-13

During 2012 *kharif* season (Table-4, Fig.3), lowest pod damage rating (DR) was recorded in ENT-11 (2) which was followed by resistant check ICPL-332 (2.87), ICP-13198 (2.93), PPE-45-2 (2.95), ICPL-97253, ICPHRL-4979-2 and ICP-10531 (2.97), ICPL-909 and ICP-990016 (3) in their order and were statistically at par with each other. Highest damage rating was noticed in BSMR-736 (6) which was followed by susceptible check ICPL-87 (5.99), ICPL-20118 (5), ICPL-4978-5 (4.99), ICPHRL-4989-7 (4.98) and ICPL-99004 (4.93) and found at par with each other.

**Table 4. Relative expression of resistance to Helicoverpa *armigera* (Hubner) on different pigeonpea genotypes during 2011-12 and 2012-13 under field conditions.**

| Treatment No. | Genotypes | Damage rating 2011-12 | Damage rating 2012-13 | Pooled Damage rating |
|---|---|---|---|---|
| $T_1$ | ICPL-20139 | 3.73 | 3.93 | 3.83 |
| $T_2$ | ICPL-20118 | 4.90 | 5.00 | 4.95 |
| $T_3$ | ICPL-99004 | 4.77 | 4.93 | 4.85 |
| $T_4$ | ICP-990016 | 2.90 | 3.00 | 2.95 |
| $T_5$ | ENT-11 | 1.90 | 2.00 | 1.95 |
| $T_6$ | ICP-10531 | 2.77 | 2.97 | 2.87 |
| $T_7$ | ICP-13198 | 2.23 | 2.93 | 2.58 |
| $T_8$ | ICPHRL-4978-5 | 4.93 | 4.99 | 4.96 |
| $T_9$ | ICPHRL-4979-2 | 3.00 | 2.97 | 2.98 |
| $T_{10}$ | ICPHRL-4985-1 | 3.93 | 3.99 | 3.96 |
| $T_{11}$ | ICPHRL-4985-10 | 3.70 | 3.92 | 3.81 |
| $T_{12}$ | ICPHRL-4989-7 | 4.73 | 4.98 | 4.86 |
| $T_{13}$ | ICPL-20062 | 3.37 | 3.92 | 3.64 |
| $T_{14}$ | ICPL-332 (R) | 2.93 | 2.87 | 2.90 |
| $T_{15}$ | ICPL-909 | 2.80 | 3.00 | 2.90 |
| $T_{16}$ | ICPL-97253 | 2.83 | 2.97 | 2.90 |
| $T_{17}$ | PPE-45-2 | 2.60 | 2.95 | 2.78 |
| $T_{18}$ | ICPL-87 (S) | 5.97 | 5.99 | 5.98 |
| $T_{19}$ | ICPL-87119 | 4.00 | 3.98 | 3.99 |
| $T_{20}$ | PKV-TARA | 3.87 | 3.98 | 3.92 |
| $T_{21}$ | AKT-8811 | 3.97 | 3.83 | 3.90 |
| $T_{22}$ | BSMR-736 | 5.90 | 6.00 | 5.95 |
| $T_{23}$ | ICPH-2671 | 3.83 | 3.98 | 3.91 |
| $T_{24}$ | ICPH-2740 | 3.83 | 3.90 | 3.87 |
| **S.Em. ±** | | **0.42** | **0.57** | **0.42** |
| **CD at 5%** | | **1.12** | **1.53** | **1.12** |
| **CV %** | | **13.80** | **18.04** | **13.42** |

R-Resistant check, S-Susceptible check.

#### 4.2.3.3 Pooled mean

Mean pod damage rating levels (Table-4, Fig.3) of *kharif* 2011 and 2012 seasons revealed that, all the tested genotypes exhibited nearly similar reaction during both the seasons. The pooled mean pod damage

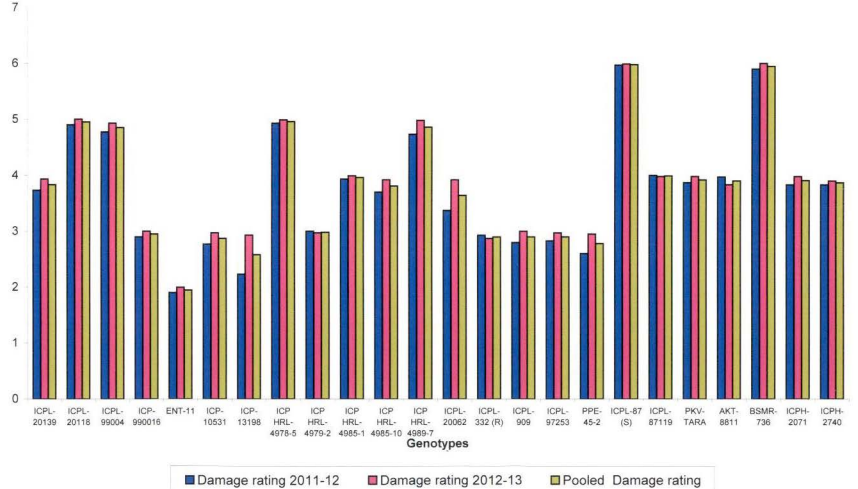



**Fig.3. Relative expression of resistance to *Helicoverpa armigera* (Hubner) on different pigeonpea genotypes during 2011-12 and 2012-13**

rating of both the trials ranged between 1.95 to 5.98. Proportion of pod damaged indicates that ENT-11 (1.95), ICP-13198 (2.58), PPE-45-2 (2.78), ICP-10531 (2.87), ICPL-97253, ICPL-909 and resistant check ICPL-332 (2.90) followed by ICP-990016 (2.95) exhibited moderate levels of resistance to *H. armigera*, and suffered significantly less damage than the susceptible check ICPL-87 which had highest damage rating (5.98) and late genotype BSMR-736 (5.95).

**4.2.4 Per cent pod damage**

**4.2.4.1 *Kharif* 2011-12**

During 2011 lowest pod damage was recorded (Table-5, Fig.4) in the genotype ENT-11 (5.17%) it was followed by resistant check ICPL-332 (9.00%), which was at par with former genotype. The genotypes ICPHRL-4979-2 registered 11.33 per cent damage and was statistically at par with ICPL-909 (12.33%), ICP-990016 and ICPL-97253. The genotype AKT-8811 recorded 17.07 per cent damage followed by ICPH-2671 (17%), ICPL- 20062 (17.67%), PKV-TARA (18.53%), ICPL-20118 (20.33%) and ICPHRL-4989-7(20.33%) showed moderate reaction. The highest per cent pod damage was observed in susceptible check ICPL-87 (24.33%) followed by BSMR-736 (22.17%).

**4.2.4.2 *Kharif* 2012-13**

During 2012 (Table -5, Fig.4), minimum per cent pod damage was observed in ENT-11 (6.77%) followed by ICPL-332 (10.50%) and was significantly less than rest of the genotypes. Maximum per cent pod damage was recorded in susceptible check ICPL-87 (27.83%) followed by ICPHRL-4978-5 (24.50%), ICPL-20118 (23.83%) and BSMR-736 (23.67%).

**4.2.4.3 Pooled mean**

Perusal of mean per cent pod damage levels of 2011 and 2012 seasons revealed that (Table-5, Fig.4), all the tested genotypes exhibited more or less similar reaction during both the seasons. The pooled mean of per cent pod damage from both the trials ranged between 5.97 to 26.08 per cent. Significantly, lowest per cent pod damage was recorded in ENT-11 (5.97%) followed by ICPL-332 (9.75%). The maximum per cent pod damage was observed in susceptible check ICPL-87 susceptible check (26.08%) followed by BSMR-736 (22.92%) and ICPHRL-4978-5 (22.50%).

**Table 5.Relative infestation of *Helicoverpa armigera* (Hubner) in different pigeonpea genotypes during 2011-12 and 2012-13 under field conditions**

| Treatment No. | Genotypes | Per cent infestation 2011-12 | Per cent infestation 2012-13 | Pooled Mean (%) |
|---|---|---|---|---|
| $T_1$ | ICPL-20139 | 15.70(3.95) | 18.87(4.34) | 17.28(4.12) |
| $T_2$ | ICPL-20118 | 20.33(4.47) | 23.83(4.87) | 22.08(4.70) |
| $T_3$ | ICPL-99004 | 20.83(4.53) | 22.33(4.72) | 21.58(4.65) |
| $T_4$ | ICP-990016 | 13.00(3.59) | 15.83(3.97) | 14.42(3.81) |
| $T_5$ | ENT-11 | 5.17(2.24) | 6.77(2.60) | 5.97(2.42) |
| $T_6$ | ICP-10531 | 13.33(3.63) | 15.50(3.93) | 14.42(3.81) |
| $T_7$ | ICP-13198 | 13.83(3.71) | 15.90(3.99) | 14.87(3.84) |
| $T_8$ | ICPHRL-4978-5 | 20.50(4.48) | 24.50(4.95) | 22.50(4.71) |
| $T_9$ | ICPHRL-4979-2 | 11.33(3.34) | 14.83(3.85) | 13.08(3.61) |
| $T_{10}$ | ICPHRL-4985-1 | 20.73(4.52) | 21.63(4.63) | 21.18(4.60) |
| $T_{11}$ | ICPHRL-4985-10 | 16.07(3.97) | 17.83(4.22) | 16.95(4.08) |
| $T_{12}$ | ICPHRL-4989-7 | 20.33(4.47) | 23.17(4.80) | 21.75(4.66) |
| $T_{13}$ | ICPL-20062 | 17.67(4.18) | 19.83(4.45) | 18.75(4.32) |
| $T_{14}$ | ICPL-332 (R) | 9.00(2.96) | 10.50(3.24) | 9.75(3.11) |
| $T_{15}$ | ICPL-909 | 12.33(3.46) | 15.50(3.94) | 13.92(3.72) |
| $T_{16}$ | ICPL-97253 | 13.17(3.59) | 14.63(3.83) | 13.90(3.72) |
| $T_{17}$ | PPE-45-2 | 13.67(3.66) | 14.50(3.81) | 14.08(3.75) |
| $T_{18}$ | ICPL-87 (S) | 24.33(4.92) | 27.83(5.27) | 26.08(5.10) |
| $T_{19}$ | ICPL-87119 | 16.00(3.95) | 18.50(4.30) | 17.25(4.11) |
| $T_{20}$ | PKV-TARA | 18.53(4.24) | 20.83(4.56) | 19.68(4.42) |
| $T_{21}$ | AKT-8811 | 17.07(4.08) | 19.17(4.37) | 18.12(4.26) |
| $T_{22}$ | BSMR-736 | 22.17(4.68) | 23.67(4.86) | 22.92(4.78) |
| $T_{23}$ | ICPH-2671 | 17.23(4.10) | 18.40(4.29) | 17.82(4.20) |
| $T_{24}$ | ICPH-2740 | 15.17(3.85) | 19.50(4.41) | 17.33(4.13) |
| **S.Em. ±** | | **0.37** | **0.41** | **0.26** |
| **CD at 5%** | | **1.07** | **1.18** | **0.75** |
| **CV %** | | **16.48** | **16.96** | **11.09** |

Figures in parentheses are square root transformed values.

R-Resistant check, S-Susceptible check

An overview of the results indicated that resistance to *H. armigera* observed in ENT-11 followed by resistant check ICPL-332, ICPHRL-4979-2, ICPL-909, PPE-45-2, ICP-990016, ICPL-97253 and ICP-13198. The next group which recorded moderate resistance viz. ICP-

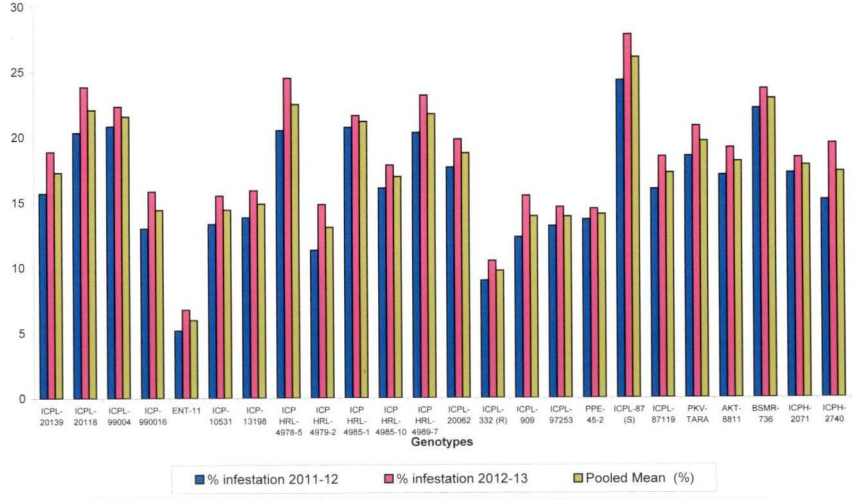



**Fig.4.Relative infestation of *Helicoverpa armigera* (Hubner) in different pigeonpea genotypes during 2011-12 and 2012-13**

10531, ICPHRL-4985-10, ICPL-20139, ICPH-2740, ICPL-87119, AKT-8811, ICPH-2671, ICPL-20062 and PKV-TARA.Whereas, susceptibility was noticed in ICPL-87, BSMR-736 and ICPHRL-4978-5. The low to moderate levels of resistance to *H. armigera* in germplasms accessions were reported by earlier worker Lateef (1985).

Patel and Patel (1990) screened 13 early and 13 midlate maturing varieties of pigeonpea against *H. armigera* but none of the entry was free from the infestation. ICRISAT (1992) reported variety ICPL-332 as tolerant to the pod borer *H. armigera* and it had on an average 35 per cent pod borer damage as against the cultivar C-11 (51% borer damaged pods). The extra-early maturing cultivars had the highest pod damage due *H. armigera* (ICPL-87, 29.6% damage) followed by C-11 (17.2 per cent pod damage) due to *H. armigera*, reported by Sahoo and Patnaik (1993) and also reported that none of the extra early genotype was free from infestation by major species pod borer (Raut et al., 1993; Mali and Patil, 1994). Minja et al., (1993) revealed that seeds from all genotypes were damaged by pod borers.

A total of 2033 accessions of pigeonpea screened against pod borer for three years by Lal and Rathore, (1999) indicated that the accessions of ICRISAT showed lower levels of pod damage compared to the control variety Bahar. Cultivars C-11, ICPL-87119, WRG-47, WRG-53 had more damage compared to other cultivars BSMR-846, AKT-9726 as reported by Surana et al. (2002). Sharma et al. (2003) revealed that all the genotypes tested showed low level of resistance.

Ujagir et al. (2005) screened 28 genotypes against *H. armigera*. Of the 28 genotypes, 9 genotypes (ICC-1151, ICC-11953, ICC-11965, ICC-11967, ICC-11969, ICC-13199, ICC-13202, ICC-13204 and ICC-13210) were found least susceptible with score of 5 on a scale of 1-9 damage rating. Kooner and Cheema (2006) screened eighty nine genotypes of pigeonpea to isolate sources of resistance to pod borers. On the basis of per cent pod damage and Pest Susceptibility Rating (PSR), entries AL-1498, AL-1502 and Al-1340 were found promising with mean pod damage of 11.21 to 13.71 per cent (PSR 3-3.50) as compared to17.67 to 26.25 per cent (PSR 4-5.50) on the check varieties (AL-15, AL-201 and T-21) .

Rizwana Banu (2007) screened fifteen germplasm lines for their resistance/tolerance to pod borer under natural infestation in pesticide-free open field. On the basis of mean infestation, ICP-13201 showed the lowest 25 per cent pod damage and showed lowest susceptibility among the genotypes studied. It was followed by ICP-13208 and ICP-11964 which had lower pod damage. The rest of the genotype suffered higher pod damage due to *Helicoverpa armigera*.

Gangwar et al. (2009) screened seventy two inter-specific plants progenies, derived by crossing with wild species viz. *C. cajanifollous, C. acutifolius* and *C. scarabaeoides* and cultivated lines viz. UPAS-120, Pant A-134, and ICPL-84023, in field to isolate sources of resistance to pod borer (*H.armigera*). All seventy two $F_3$ progenies of 9 inter specific hybrids evaluated for their reaction to the infestation of pod borer showed very low level of pod and seed damage as compared to pod and seed damage in cultivated lines.

Anitha Kumari et al. (2010[b]) reported the genotypes ICPL 187-1, ICP 7203-1, ICPL 98008, T- 21, ICP- 7035, and ICPL- 332 exhibited moderate levels of resistance to *H. armigera* across planting dates. From fore going discussion it has been observed that, the information pertaining to the genotypes screened under present investigation is scanty. However, ICRISAT (1992) and Anitha Kumari et al., (2010[b]) have reported ICPL-332 as moderately resistance to *H. armigera*. Whereas, ICPL-87, ICPL-87119 showed susceptible reaction as reported by Anitha Kumari et al., (2010[b]), Surana et al., (2002), respectively which corroborates the present findings.Among the late group genotypes ENT-11, ICPL-332 registered as some what resistant.Whereas, BSMR-736,ICPI-20118 and ICPL-99004 emerged as susceptible in late genotypes during the present investigations.

As far as number of eggs and larvae per plant and damage rating is concerned it was lowest in ENT-11 (1.95) compared to resistant check ICPL-332 (2.90) whereas, susceptible check ICPL-87 could harbour maximum eggs, larvae of H. *armigera* and had highest damage rating (5.98). Anitha Kumari et al., (2010[b]) reported more or less similar types of reaction of the above said genotypes (except ENT-11) under field conditions. Agronomic traits viz. Days to 50% flowering and days to

maturity also influences the per cent pod infestation and ultimately the damage ratings. Susceptible genotype ICPL-87 had early 50% flowering as well as maturity (82 days and 119 days, respectively) and might have prone to more damage by H. *armigera* besides other factors. Resistant genotype ENT-11 had taken longest period for 50% flowering (121 days) followed by maturity (183 days) which might have escaped from the attack of *H. armigera* besides other factors. Naresh et al. (1983) and Sahoo and Patnaik (1993) in general have rported extra-early genotypes prone to have more damage which is in conformity with the present investigation. During the present investigation late genotype ENT-11 and ICPL-332 emerged as resistant which are somewhat not in agreement to the findings of Bhosale and Nawale (1983), who reported in general medium late entries were significantly less damaged than late.

**4.2.5 Grain yield per hectare**

**4.2.5.1 Kharif 2011-12**

During *kharif* 2011-12 the yield data (Table-6, Fig.5) revealed that PKV-TARA recorded significantly highest yield (16.44q/ha). However, it was at par with ICPL-97253 (16.31q/ha), ICPL-909, AKT-8811 (15.48q/ha), PPE-45-2 (15.12q/ha), ICPL-332 (14.35q/ha), ICP-10531 (14.30q/ha), ICPL-87119 (13.89q/ha), ICPL-20062 (13.37q/ha) and ICPL-20139 (13.32q/ha). Lowest yield was recorded in ENT-11 (6.17q/ha) which was followed by ICPL99004 (7.15q/ha) in late group and susceptible check ICPL-87 (7.46q/ha) in early group.

**4.2.5.2 *Kharif* 2012-13**

During 2012-13 grain yield (Table-6, Fig.5) was highest in ICPL-87119 (19.55q/ha) followed by PKV-TARA (18.93q/ha), PPE-45-2 (18.11q/ha), ICP-13198 (17.9q/ha), ICPL-97253 (17.54), ICP-10531 (17.39q/ha),ICPH- 2740 (16.98q/ha), ICPL-332 (16.77q/ha), AKT-8811 (16.72q/ha), ICPL-909 (16.57q/ha), ICPL-990016 (16.46q/ha), ICPHRL-4979-2 (16.36q/ha) and ICPL-20139 (16.15q/ha) and were at par with each other. Lowest grain yield was recorded in ENT-11 (7.5q/ha) which was followed by ICPL-87 (7.85q/ha), ICPL-99004 (8.79q/ha) and ICPL-20118 (10.08q/ha).

**Table 6. Yield obtained from different pigeonpea genotypes during 2011-12 and 2012-13**

| Treatment No. | Genotypes | Yield qt/ ha 2011-12 | Yield qt/ ha 2012-13 | Pooled Mean qt/ ha | Rank |
|---|---|---|---|---|---|
| $T_1$ | ICPL-20139 | 13.32 | 16.15 | 14.74 | 10 |
| $T_2$ | ICPL-20118 | 8.13 | 10.60 | 9.36 | 21 |
| $T_3$ | ICPL-99004 | 7.15 | 8.79 | 7.98 | 22 |
| $T_4$ | ICP-990016 | 12.66 | 16.46 | 14.56 | 13 |
| $T_5$ | ENT-11 | 6.17 | 7.51 | 6.84 | 24 |
| $T_6$ | ICP-10531 | 12.96 | 17.39 | 15.18 | 9 |
| $T_7$ | ICP-13198 | 14.30 | 17.90 | 16.10 | 5 |
| $T_8$ | ICPHRL-4978-5 | 8.85 | 10.08 | 9.46 | 20 |
| $T_9$ | ICPHRL-4979-2 | 12.76 | 16.36 | 14.56 | 14 |
| $T_{10}$ | ICPHRL-4985-1 | 9.87 | 12.34 | 11.11 | 19 |
| $T_{11}$ | ICPHRL-4985-10 | 10.96 | 13.43 | 12.19 | 17 |
| $T_{12}$ | ICPHRL-4989-7 | 10.49 | 12.45 | 11.47 | 18 |
| $T_{13}$ | ICPL-20062 | 13.37 | 15.79 | 14.58 | 12 |
| $T_{14}$ | ICPL-332 (R) | 14.35 | 16.77 | 15.56 | 8 |
| $T_{15}$ | ICPL-909 | 15.48 | 16.57 | 16.02 | 7 |
| $T_{16}$ | ICPL-97253 | 16.31 | 17.54 | 16.92 | 2 |
| $T_{17}$ | PPE-45-2 | 15.12 | 18.11 | 16.62 | 4 |
| $T_{18}$ | ICPL-87 (S) | 7.46 | 7.85 | 7.66 | 23 |
| $T_{19}$ | ICPL-87119 | 13.89 | 19.55 | 16.72 | 3 |
| $T_{20}$ | PKV-TARA | 16.44 | 18.93 | 17.69 | 1 |
| $T_{21}$ | AKT-8811 | 15.48 | 16.72 | 16.10 | 6 |
| $T_{22}$ | BSMR-736 | 12.55 | 13.27 | 12.91 | 16 |
| $T_{23}$ | ICPH-2671 | 12.43 | 15.64 | 14.03 | 15 |
| $T_{24}$ | ICPH-2740 | 12.24 | 16.98 | 14.61 | 11 |
| **S.Em. ±** | | **1.16** | **1.20** | **0.93** | |
| **CD at 5%** | | **3.30** | **3.43** | **2.64** | |
| **CV %** | | **16.44** | **14.17** | **11.92** | |

R-Resistant check, S-Susceptible check

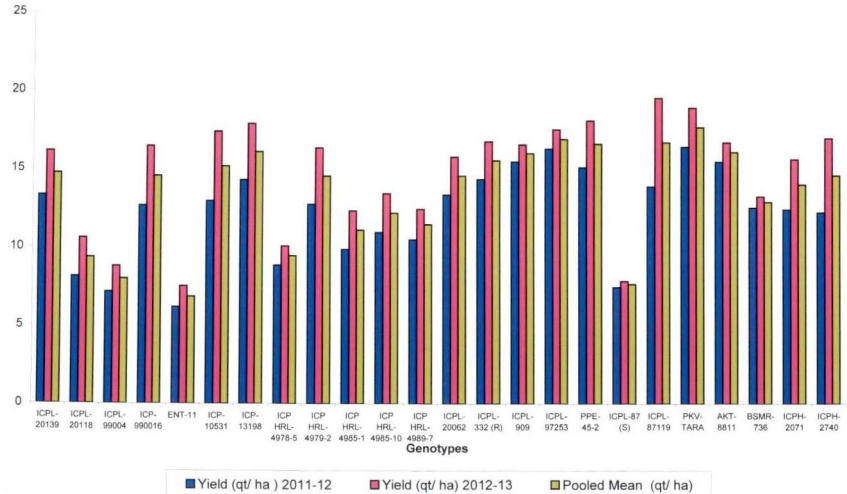



**Fig.5. Yield obtained from different pigeonpea genotypes during 2011-12 and 2012-13**

#### 4.2.5.3 Pooled mean

The pooled data (Table-6, Fig.5) on grain yield q/ha obtained from different genotypes of pigeonpea indicates that PKV-TARA recorded highest yield (17.69q/ha). However, it was at par with ICPL-97253 (16.92q/ha), ICPL-87119 (16.72q/ha), PPE-45-2 (16.62q/ha), ICP-13198 (16.10q/ha), AKT-8811 (16.10q/ha), ICPL-909 (16.02q/ha), ICPL-332 (15.56q/ha), and ICP-10531 (15.18q/ha). Next to these an agronomically superior genotypes were ICPL-20139 (14.74q/ha), ICPH- 2740 (14.61q/ha), ICPL-20062 (14.58q/ha), ICP-990016 (14.56q/ha), ICPHRL-4979-2 (14.56q/ha), ICPH-2671 (14.03q/ha), BSMR-736 (12.91q/ha) and ICPHRL-4985-10 (12.19q/ha) performed well and found to be at par with each other. Lowest yield was recorded in ENT-11 (6.84q/ha) and showed poor performance in recording yield though it was found resistant to *H. armigera* might be due to genotypic characters. Next genotype in lower yield was ICPL-87 (7.66q/ha) followed by ICPL-99004 (7.98q/ha) and ICPL-20118 (9.36q/ha) due to higher pest load ultimately due to higher damage compared to rest of the genotypes except ENT-11.

In general, PKV-TARA was found most promising during these investigations in recording highest yield. ICPL-97253, ICPL-87119, PPE-45-2, ICP13198, AKT-8811, ICPL-909, ICPL-332 and ICP10531 were ranked as next promising group of genotypes in respect of yield performance as they were found at par with high yielding genotype PKV-TARA.

The overall results from the data (Table-5 and Fig.4) revealed that most of the genotypes which recorded higher yields were equally tolerant to the damage done by *H. armigera* whereas, low yielding genotypes were almost susceptible with some exceptions *viz.* ENT-11 and ICPL-332. Considering the yield potential ICP-13201, ICP-13214 and ICP-13212 showed higher yield potential than other genotypes. Considering the lower susceptibility to *H. armigera* and higher yield potential ICP-13201 was found to be the best (Rizwana Banu, 2007).

Anitha Kumari et al. (2010) evaluated ICPL 187-1, ICP 7203-1, ICPL-84060, ICPL-87119 and ICPL-332 which had better grain yield potential than the susceptible checks, ICPL-87 and ICPL-87091.They

further reported that grain yield of most of the genotypes under *H. armigera* infestation was also unstable, except that of ICPL-87119, ICP-7035 and ICPL-332.

Grain yield of PKV-TARA, ICPL-87119, AKT-8811, ICPL-20139, and ICPH-2740 was on par with resistant check ICPL-332. The principal component analysis grouped the genotypes into four groups, suggesting that there is considerable diversity among the pigeonpea genotypes in their susceptibility to pod borer damage, and genotypes ICPL-332, ICPHRL-4979-2, ICP-990016, ICPL-97253, PPE-45-2, ICP-13198, ICPL-909, ICPL-20062 and ICP-10531 with different levels of resistance to pod borer, were placed in separate groups. The genotypes PKV-TARA, ICPL-87119, AKT-8811, ICPL-20139, and ICPH-2740 which showed moderate resistance to *H. armigera*, exhibited high grain yield potential under natural infestation, and there is good potential for increasing the levels and diversifying the basis of resistance to pod borer for pigeonpea improvement. Thus more or less moderately resistant genotypes to *H. armigera* yielded equally more. This is in general agreement with the previous findings except in case of ENT-11.

**4.3 Mechanism of host plant resistance in pigeonpea to *H. armigera***

a. Non-preference/Antixenosis
b. Antibiosis
c. Tolerance

In the present investigation, 24 genotypes were evaluated for mechanisms of resistance to pod borer *H. armigera* . Three types of resistance mechanisms; antixenosis, antibiosis and tolerance were recorded and studied. The former two studies were carried out in laboratory conditions and later one in field conditions.

**4.3.1 Non-preference/ antixenosis for oviposition to *H. armigera* (No choice test)**

Under no-choice test each genotype was tested in a wooden cage (30x30x45cm). 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 two day old moths were released inside the cage. Moths were provided with sucrose solution in a cotton swab throughout the experiment.

**Table 7. Relative oviposition preference by *H. armigera* on different genotypes of pigeonpea under no choice cage test.**

| Sr. No | Genotype | No. of eggs laid | ROP |
|---|---|---|---|
| 1 | ICPL-20139 | 145 (12.04) | -19.22 |
| 2 | ICPL-20118 | 162 (12.73) | -13.82 |
| 3 | ICPL-99004 | 149 (12.21) | -17.90 |
| 4 | ICP-990016 | 160 (12.65) | -14.43 |
| 5 | ENT-11 | 67 (8.19) | -52.31 |
| 6 | ICP-10531 | 123 (11.09) | -27.00 |
| 7 | ICP-13198 | 127 (11.27) | -25.51 |
| 8 | ICPHRL-4978-5 | 143 (11.96) | -19.88 |
| 9 | ICPHRL-4979-2 | 108 (10.39) | -23.91 |
| 10 | ICPHRL-4985-1 | 149 (12.21) | -17.90 |
| 11 | ICPHRL-4985-10 | 134 (11.58) | -22.98 |
| 12 | ICPHRL-4989-7 | 172 (13.11) | -10.88 |
| 13 | ICPL-20062 | 137 (11.70) | -21.93 |
| 14 | ICPL-332 (R) | 108 (10.39) | -32.91 |
| 15 | ICPL-909 | 117 (10.82) | -29.30 |
| 16 | ICPL-97253 | 118 (10.86) | -28.91 |
| 17 | PPE-45-2 | 136 (11.66) | -22.28 |
| 18 | ICPL-87(S) | 214(14.63) | ----- |
| 19 | ICPL-87119 | 145 (12.04) | -19.22 |
| 20 | PKV-TARA | 143 (11.96) | -19.88 |
| 21 | AKT-8811 | 138 (11.75) | -21.59 |
| 22 | BSMR-736 | 160 (12.65) | -14.43 |
| 23 | ICPH-2671 | 144 (12.00) | -19.27 |
| 24 | ICPH-2740 | 145 (12.04) | -19.22 |
| **S.Em. ±** | | **7.34** | |
| **CD at 5%** | | **19.66** | |
| **CV %** | | **6.45** | |

Figures in parentheses are square root transformed values.

R-Resistant check, S-Susceptible check.

ROP= Relative oviposition preference in relation to ICPL-87.

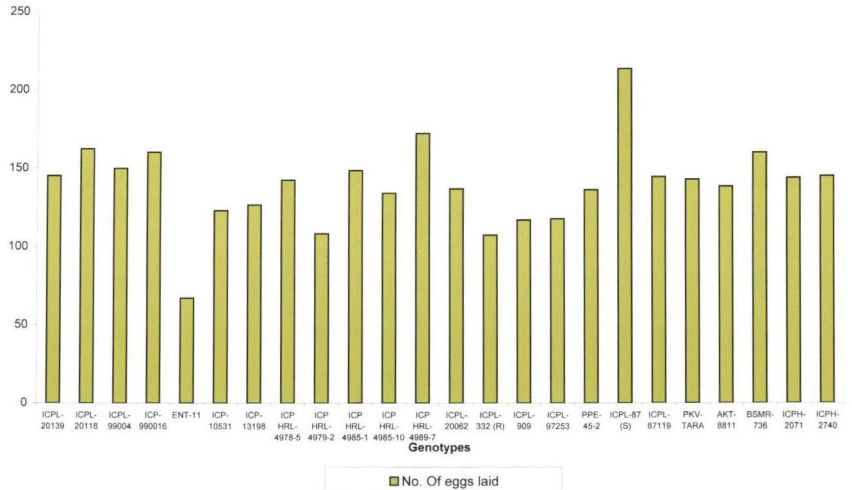



**Fig.6. Relative oviposition preference by *H. armigera* towards different genotypes of pigeonpea under no choice conditions.**

After releasing the moth in the cages, those were allowed to oviposit for three consecutive nights on the test plants. Data regarding oviposition (Table 7, Fig.6) revealed that each female moth laid 67 to 214 eggs on different test genotypes. Among the genotypes tested on ENT-11 least egg layings was noticed (67 eggs per female) which was significantly lowest than rest of the genotypes. There were 108 eggs per female on ICPL-332 (resistance check) compared to 214 eggs on ICPL-87 (susceptible check). Former was followed by ICPL-332, ICPHRL-4979-2, (108 eggs), ICPL-909 (117 eggs), ICPL-97253 (118 eggs), ICP-10531 (123 eggs) and ICP-13198 (127 eggs) and were at par with each other. Significantly highest egg layings were observed on Susceptible check ICPL-87 (214 eggs), which was highly preferred for oviposition by *H. armigera*. While, genotypes ICPHRL-4989-7 (172 eggs), ICPL-20118 (162 eggs), ICPL-99004 and BSMR-736 (160 eggs) were preferred as intermediate substrate for oviposition. The Relative Oviposition Preference (ROP) for all the test genotypes was lower than ICPL-87. (Table -7, Fig 5)

### 4.3.2 Non-preference/ antixenosis for oviposition to *H. armigera* (Dual choice test)

The data regarding oviposition under dual choice conditions (Table-8, Fig.7) revealed that significantly less number of eggs laid on ENT-11 (27.26 eggs) followed by ICP-10531 (32.42 eggs), PKV-TARA (38.72 eggs), ICP-13198 (39.27 eggs), ICPH-2740 (39.48 eggs), and ICPL-97253 (46.72 eggs) as compared to the susceptible genotype ICPL-87. The Relative Oviposition Preference for all the test genotypes was lower than ICPL-87. Among all the tested genotypes lowest (ROP) was recorded in ENT-11 (-44.80) followed ICPHRL-4979-2 (-29.93), ICPL-332 (-25.32), ICPL-97253 (-23.17), ICP-13198 (-22.94) and ICP-10531 (-21.06) as compared to the susceptible genotype ICPL-87.

**Table 8. Relative oviposition preference by *H. armigera* (Hubner) towards different genotypes of pigeonpea under dual choice cage test.**

| Sr. No | Genotype | Total number of eggs laid | | t-value | ROP |
|---|---|---|---|---|---|
| | | Test genotype | ICPL-87 (S) | | |
| 1 | ICPL-20139 | 59.60 | 79.20 | 8.82* | -14.12 |
| 2 | ICPL-20118 | 59.40 | 64.44 | 10.16 | -4.06 |
| 3 | ICPL-99004 | 49.22 | 68.74 | 14.95 | -16.54 |
| 4 | ICP-990016 | 46.33 | 68.80 | 7.43 | -19.51 |
| 5 | ENT-11 | 27.26 | 70.84 | 16.78 | -44.80 |
| 6 | ICP-10531 | 32.42 | 49.72 | 6.50 | -21.06 |
| 7 | ICP-13198 | 39.27 | 62.66 | 7.79 | -22.94 |
| 8 | ICPHRL-4978-5 | 43.48 | 56.10 | 13.27 | -12.67 |
| 9 | ICPHRL-4979-2 | 39.07 | 72.45 | 6.03 | -29.93 |
| 10 | ICPHRL-4985-1 | 72.44 | 86.50 | 10.59 | -8.84 |
| 11 | ICPHRL-4985-10 | 48.69 | 72.46 | 5.43 | -19.62 |
| 12 | ICPHRL-4989-7 | 50.45 | 68.22 | 13.70 | -14.97 |
| 13 | ICPL-20062 | 68.70 | 93.44 | 9.27 | -15.25 |
| 14 | ICPL-332 (R) | 48.74 | 82.70 | 17.37 | -25.82 |
| 15 | ICPL-909 | 51.22 | 75.67 | 12.87 | -19.26 |
| 16 | ICPL-97253 | 46.72 | 74.90 | 6.25 | -23.17 |
| 17 | PPE-45-2 | 46.94 | 71.24 | 6.02 | -20.56 |
| 18 | ICPL-87119 | 48.92 | 70.65 | 12.25 | -18.17 |
| 19 | PKV-TARA | 38.72 | 55.28 | 5.06 | -17.61 |
| 20 | AKT-8811 | 53.24 | 75.61 | 18.22 | -17.36 |
| 21 | BSMR-736 | 58.20 | 61.39 | 1.19 | -2.66 |
| 22 | ICPH-2671 | 47.48 | 66.92 | 2.24 | -16.99 |
| 23 | ICPH-2740 | 39.48 | 56.22 | 17.68 | -17.49 |

Significant at P= 0.05

R-Resistant check, S-Susceptible check.

ROP= Relative oviposition preference in relation to ICPL-87.

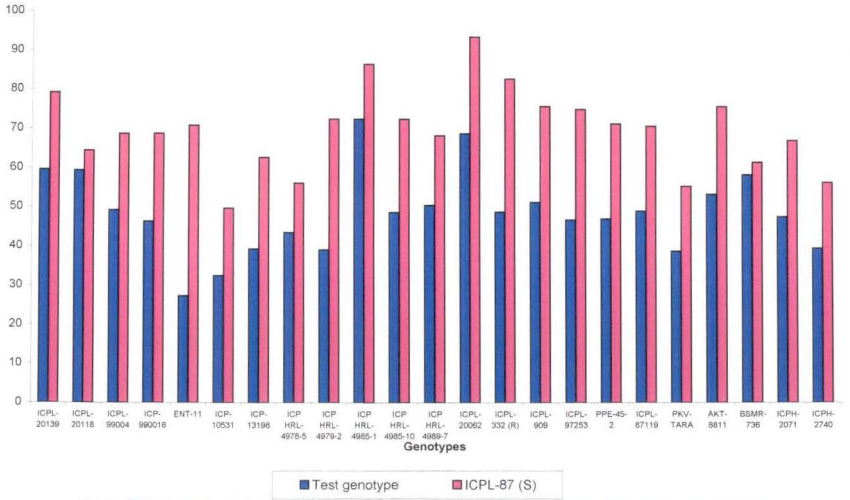



**Fig.7. Relative oviposition preference by *H. armigera* (Hubner) towards different genotypes of pigeonpea under dual choice conditions**

### 4.3.3 Non-preference/ antixenosis for oviposition to *H. armigera* (Multi choice test)

Data pertaining to oviposition by *H. armigera* female on different genotypes under multi choice test (Table-9, Fig.8) revealed that the female moths laid on an average 78 eggs (ICPL-332) to 181 eggs (ICPL-87).

**Table 9. Relative oviposition preference by *H. armigera* (Hubner) towards different genotypes of pigeonpea under multi choice test .**

| Sr. No | Genotype | No. of eggs laid | ROP |
|---|---|---|---|
| 1 | ICPL-20139 | 128 (11.31) | -17.15 |
| 2 | ICPL-20118 | 138 (11.75) | -13.65 |
| 3 | ICPL-99004 | 125 (11.18) | -18.30 |
| 4 | ICP-990016 | 110 (10.49) | -24.39 |
| 5 | ENT-11 | 56 (7.48) | -52.74 |
| 6 | ICP-10531 | 107(10.34) | -39.36 |
| 7 | ICP-13198 | 111 (10.54) | -23.97 |
| 8 | ICPHRL-4978-5 | 127 (11.27) | -17.53 |
| 9 | ICPHRL-4979-2 | 104 (10.20) | -27.01 |
| 10 | ICPHRL-4985-1 | 135 (11.62) | -14.55 |
| 11 | ICPHRL-4985-10 | 114 (10.68) | -22.71 |
| 12 | ICPHRL-4989-7 | 132 (11.49) | -18.53 |
| 13 | ICPL-20062 | 120 (10.95) | -20.26 |
| 14 | ICPL-332 (R) | 78 (8.83) | -39.76 |
| 15 | ICPL-909 | 104 (10.20) | -27.01 |
| 16 | ICPL-97253 | 117 (10.82) | -21.47 |
| 17 | PPE-45-2 | 117 (10.82) | -21.47 |
| 18 | ICPL-87 (S) | 181 (13.47) | ---- |
| 19 | ICPL-87119 | 117 (10.82) | -21.47 |
| 20 | PKV-TARA | 118 (10.86) | -21.94 |
| 21 | AKT-8811 | 118 (10.86) | -21.94 |
| 22 | BSMR-736 | 155 (12.45) | -7.73 |
| 23 | ICPH-2671 | 117 (10.82) | -21.47 |
| 24 | ICPH-2740 | 120 (10.95) | -20.26 |
| **S.Em. ±** | | **4.91** | |
| **CD at 5%** | | **13.16** | |
| **CV %** | | **5.06** | |

Figures in parentheses are square root transformed values.

R-Resistant check, S-Susceptible check.

ROP= Relative oviposition preference in relation to ICPL-87.

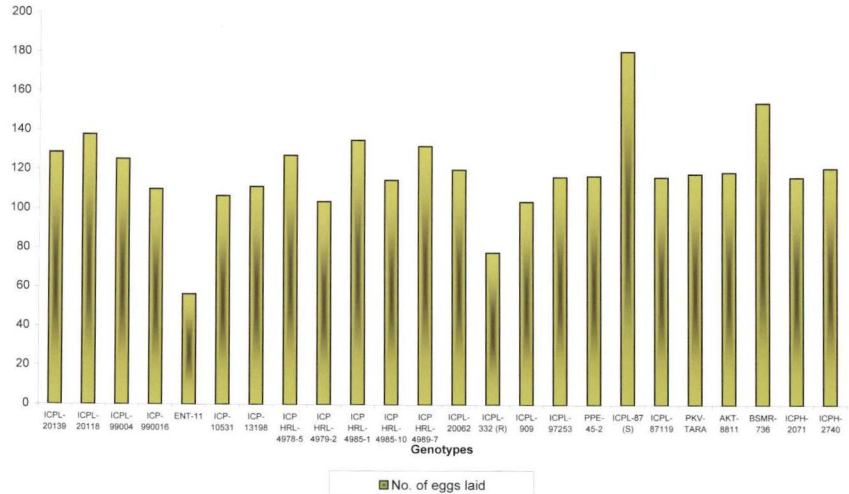



**Fig.8. Relative oviposition preference by *H. armigera* (Hubner) towards different genotypes of pigeonpea under multi choice conditions**

Oviposition was significantly lower on ENT-11 (56 eggs) followed by ICPL-332 (78 eggs), ICPHRL-4979-2, ICPL-909 (104 eggs), ICP-10531 (107 eggs), ICP-13198 (111 eggs), ICPHRL- 4985-10 (114 eggs), PPE-45-2, ICPL-97253, ICPL-87119 and ICPH-2740 (117 eggs) when compared with that on susceptible check ICPL-87 (181 eggs). Genotypes BSMR-736 (155 eggs), ICPL-20118 (138 eggs) were as much preferred for oviposition as the susceptible check, ICPL-87. Relative Oviposition Preference (ROP) in relation to ICPL-87 was negative for all genotype tested.

Antixenosis for oviposition under no-, dual-, and multi-choice was observed in case of ENT-11, ICPL-332, ICPHRL-4979-2, ICP-13198, ICP-10531, PPE-45-2, ICPL-97253, ICPL-909, and ICPL-87119. The *H. armigera* female showed moderate levels of preference/ non-preference for oviposition towards ICP-990016,ICPL-20062, ICPH-2740, ICPH-2671, ICPHRL-4985-10 and PKV-TARA The susceptible check ICPL-87 was highly preferred for oviposition under no-, dual-, and multi-choice conditions.

The above findings are in the tune to the results of previous workers; Courtney and Kibota (1990) suggested that the host selection behavior of an insect depends on its physiological state including age, feeding status, mated status and load. *H.armigera* lays more eggs on most preferred genotype. Schoonhoven (1990) reported that preference of *H. armigera* to particular genotype, shown by laying more eggs. Pigeonpea genotypes showing resistance to *H. armigera* under field conditions exhibited oviposition non-preference under laboratory conditions also (ICRISAT, 1991).

The similar findings were also reported by Sison et al. (1993) they observed that oviposition preference under no-choice and multi-choice conditions with six pigeonpea genotypes. Among those, 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, almost six times as many as on ICPL-87101 which had the lowest number of eggs. King (1994) reported that on pigeonpea; most of the eggs are laid on flowers and flower buds, and sparingly on the leaves mostly during the vegetative phase of host.

Laxmipathi (2000) studied the influence of flower colour on oviposition preference by *H. armigera* in pigeonpea and it was found that yellow colored flowers were preferred over pink flowers. Heavy oviposition has earlier been recorded on ICPL-87, both under field and laboratory conditions (Sharma et al., 2001).

Anitha kumari et al. (2006) studied the antixenosis mechanism of resistance to *H. armigera* in a diverse array of pigeonpea genotypes under no choice, dual-choice and multi-choice conditions. Antixenosis for oviposition was observed in case of ICPL-187-1, ICP-7203-1, ICPL-88039, T-21, ICPL-84060 and ICPL-332 under no-choice, dual-choice and multi-choice conditions. The susceptible check, ICPL-87 was highly preferred for oviposition under no-, dual- and multi-choice conditions Antixenosis for oviposition observed under laboratory conditions was also exhibited under field conditions.

Sujana et al. (2008) evaluated a diverse array of wild relatives of pigeonpea for oviposition non-preference components of resistance to *H. armigera*. The accessions ICPW-1 (*Cajnus acutifolius*), ICPW-13 and 14 (*C. albicans*), ICPW-159 and 160 (*C. sericeus*), ICPW-68 (*C. platycarpus*), ICPW-83, 90, 94, 125, 137, 141 and 280 (*C. scarabaeoides*), ICPW-207 (*Paracalyx scariosa*) and ICPW-210 (*Rhynchosia aurea*) showed high levels of antixenosis for oviposition under no-choice, dual-choice and multi-choice conditions. Sharma et al. (2009) observed that among the wild relatives, oviposition non-preference was an important component of resistance in *C. scarabaeoides* while heavy egg-laying was recorded on *C. cajanifolius* (ICPW-28) and *Rhynchosia bracteata* (ICPW-214). Accessions belonging to *Rhynchosia aurea, C. scarabaeoides, Cajnus acutifolius, Flemingia bracteata and C. sericeus* showed high level of resistance to *H. armigera* while C. *cajanifolius* were as susceptible to *H. armigera* as the cultivated pigeonpea. Among the cultivated pigeonpea genotypes, ICPL-332 (the resistant check) was consistently less damaged than the susceptible check, ICPL-87.

From the foregoing discussion it has been inferred that susceptible genotypes had more eggs of *H. armigera* that might be due to certain biochemical cues leading to high preference by the female moth to oviposit on the substrate. On the contrary resistant genotypes recorded less eggs might be due to deterrent tendency. Thus, the present findings are in close proximity with the findings of previous workers.

**4.3.4 Antibiosis**

The rearing of pod borer *H. armigera* on flowers and pods of different genotypes was done under laboratory conditions. Twelve neonate larvae, constituting a replication were reared individually in each petri plates with moistened filter paper attached to the lid until pupation and were replicated four times.

**4.3.4.1 Growth of *H. armigera* reared on flowers and pods of different genotypes of pigeonpea.**

**i) Larval mortality**

**a) At 5$^{th}$ day**

Larvae reared on flowers and pods of pigeonpea genotypes (Table-10, Fig.9) revealed that mortality of larvae at 5$^{th}$ days after initiation of experiment was highest in ENT-11 (18.33%) which was statistically at par with ICPL-97253 (17.67%), ICPHRL-4979-2 (17%), ICPL-332 (16.67%) and ICPL-20139. Lowest per cent mortality was recorded in ICP-99004 and ICPL-20118 (9.67%) which was followed by ICPL-87, ICPHRL-4989-7 and ICPHRL-4985-1 (10%) and was found on par with each other.

**b) At 10$^{th}$ day**

Highest mortality was recorded in ICPHRL-4979-2 (35%) at 10 days after initiation of experiment which was followed by ENT-11 and ICPL-332 (32.67%), PPE-45-2 (30.67%), ICP-13198 and ICPL-97253 (30.33%) and was statistically at par with each other. Lowest mortality was observed in BSMR-736, ICPL-87, ICPL-20118 and ICPHRL-4985-1(19.33%) which was followed by ICPHRL-4978-5 (21.67%) and ICPHRL-4989-7 (23.67%).

**c) At 15$^{th}$ day**

Mortality of larvae at 15 days after initiation of experiment was highest in ICPHRL-4979-2 (37.33%) which was statistically at par with

ENT-11 (37%), ICP-10531, ICPL-332, and ICPL-97253 (35%), PPE-45-2 (34.67%), and ICPL-990016 (33.67). Lowest mortality was recorded in BSMR-736, ICPL-87, ICPL-20118 and ICPL-99004, (24%) which were followed by ICPH-2671, AKT-8811 and PKV-TARA (26%).

**Table 10. Mortality of *H. armigera* (Hubner) larvae reared on flowers and pods of different pigeonpea genotypes.**

| Sr. No | Genotype | Larval mortality (%) | | |
|---|---|---|---|---|
| | | day5th | day10th | day15th |
| 1 | ICPL-20139 | 14.67(3.82)* | 26.00 (30.65)** | 28.33(32.23)** |
| 2 | ICPL-20118 | 9.67 (3.09) | 19.33(26.06) | 24.00(29.30) |
| 3 | ICPL-99004 | 9.67 (3.09) | 24.00(29.30) | 24.00(29.30) |
| 4 | ICP-990016 | 12.33(3.49) | 28.00(31.95) | 33.67(35.43) |
| 5 | ENT-11 | 18.33( 4.27) | 32.67(34.83) | 37.00(37.45) |
| 6 | ICP-10531 | 14.33 (3.78) | 28.33(32.13) | 35.00(36.27) |
| 7 | ICP-13198 | 14.33 (3.78) | 30.33(33.37) | 30.67(33.56) |
| 8 | ICPHRL-4978-5 | 12.33(3.49) | 21.67(27.69) | 28.33(32.06) |
| 9 | ICPHRL-4979-2 | 17.00 (4.12) | 35.00(36.27) | 37.33(37.65) |
| 10 | ICPHRL-4985-1 | 10.00(3.16) | 19.33(25.96) | 26.00(30.62) |
| 11 | ICPHRL-4985-10 | 12.33(3.49) | 26.00(30.65) | 30.67(33.60) |
| 12 | ICPHRL-4989-7 | 10.00(3.16) | 23.67(29.10) | 26.00(30.62) |
| 13 | ICPL-20062 | 12.33(3.49) | 24.00(29.30) | 26.00(30.62) |
| 14 | ICPL-332 (R) | 16.67(4.08) | 32.67(34.83) | 35.00(36.24) |
| 15 | ICPL-909 | 14.33(3.78) | 26.00(30.65) | 34.67(36.06) |
| 16 | ICPL-97253 | 17.67(4.20) | 30.33(33.39) | 35.00(36.26) |
| 17 | PPE-45-2 | 12.33(3.50) | 30.67(33.62) | 30.67(33.56) |
| 18 | ICPL-87 (S) | 10.00(3.16) | 19.33(25.96) | 24.00(29.30) |
| 19 | ICPL-87119 | 14.67(3.82) | 26.00(30.64) | 28.33(32.13) |
| 20 | PKV-TARA | 12.33(3.49) | 24.00(29.30) | 26.00(30.62) |
| 21 | AKT-8811 | 12.33(3.49) | 24.00(29.30) | 26.00(30.62) |
| 22 | BSMR-736 | 12.33(3.48) | 19.33(25.96) | 24.00(29.30) |
| 23 | ICPH-2671 | 14.67(3.83) | 24.00(29.30) | 26.00(30.62) |
| 24 | ICPH-2740 | 12.33(3.49) | 24.00(29.30) | 28.00(31.95) |
| **S.Em. ±** | | **0.29** | **1.86** | **2.04** |
| **CD at 5%** | | **0.77** | **4.98** | **5.47** |
| **CV %** | | **9.75** | **7.49** | **7.63** |

* Figures in parentheses are square root transformed values

** Figures in parentheses are arc sine transformed values

R-Resistant check, S-Susceptible check.

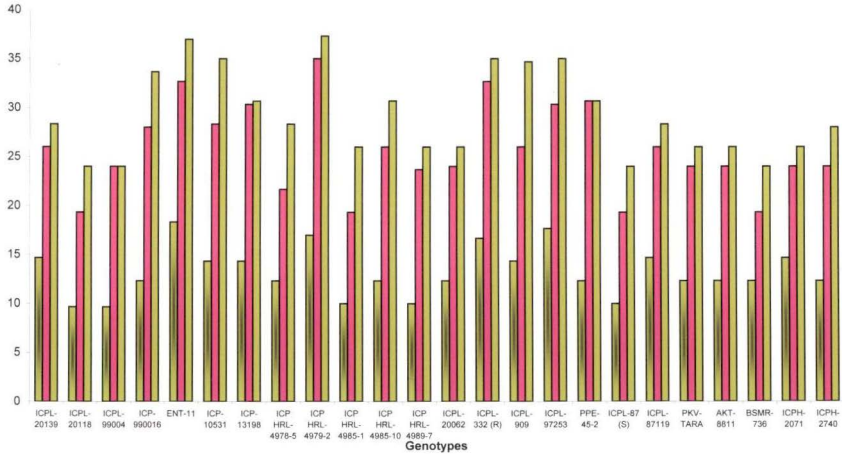



**Fig.9. Mortality of *H. armigera* (Hubner) larvae reared on flowers and pod of different pigeonpea genotypes**

**ii) Larval period**

Larvae reared on the flowers and pods of ENT-11 and ICPL-332 recorded prolonged larval period (21 days), which was statistically at par with ICPL-909 (20 days), ICPL-990016 and ICPL-97253 (19.67 days), ICPL-20139 (19.33 days), ICPHRL-4979-2, PPE-45-2, ICPL-87119, PKV-TARA and ICPH-2740 (19 days). Larvae reared on flowers and pods of susceptible check ICPL-87 registered shortest larval period (17.33 days) followed by BSMR-736 (17.67 days). Larval period of larvae reared on flowers and pods of rest of genotypes ranged between 17.67 days to 18.67 days. (Table-11 Fig.10)

**iii) Larval weight**

The weights of larvae at 5 days of initiation of experiment (Table-12, Fig. 11) on the flowers and pods was lowest on ICP-13198 (14.2 mg) followed by PPE-45-2 (14.4 mg), ENT-11 (14.67 mg), ICPHRL-4979-2 (14.7 mg), ICPL-990016 (14.93), ICP-10531(15.03 mg), ICPL-332 (15.2 mg) and ICPL-97253 (15.33 mg), which were statistically at par with each other.

Moderate larval weight was recorded in ICPL-909 (16.83 mg) ICPH-2671 (16.77 mg) ICPL-87119 (16.4 mg), ICPH-2740 (16.1 mg), ICPHRL-4985-10 (15.83 mg), AKT-8811 (15.63 mg), PKV-TARA (15.50 mg) and ICPL-20139 (15.43 mg) in their order and were at par with each other.

Maximum larval weight was observed in ICPL-20118 (20.03 mg) which was statistically at par with ICPL-87 (19.23 mg), BSMR-736 (19.13 mg) and ICPHRL-4987-5 (18.47 mg)

The lowest weight of the larva at 10 days after initiation of experiment on the flowers and pods of ICP-13198 was 172 mg followed by ENT-11 (173 mg), ICPL-20062 (178 mg), ICPHRL-4985-10 (178.33 mg), ICPL-97253 ( 179.33 mg), ICPL-332 (181 mg) and ICP-10531 (181.63 mg) were lower compared to the larvae reared on ICPL-87 (235.66 mg) which was significantly highest than rest and followed by ICPHRL-4989-7 (230 mg), ICPHRL-4978-5, ICPL-20118 (205.67 mg), and ICPL-99004 (202.67 mg) in their order.

**Table 11. Development of *H. armigera* larvae reared on flowers and pods of different pigeonpea genotypes.**

| Sr. No | Genotype | Larval period (days) | Pupal period (days) | Pupation (%) | Adult emergence (%) | Growth Index | Female/ Male ratio | Av. Fecundity/ Female | Hatchability (%) | Longevity Male (days) | Longevity Female (days) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ICPL-20139 | 19.33 | 11.33 | 52.50(46.43)** | 48.00 (43.85)** | 1.56 | 1.52 | 172.00 | 47.12 (43.35)** | 5.67 | 8.00 |
| 2 | ICPL-20118 | 18.00 | 10.50 | 66.50(54.64) | 56.00(48.45) | 1.96 | 2.47 | 236.33 | 50.22 (45.13) | 7.00 | 9.00 |
| 3 | ICPL-99004 | 18.67 | 10.50 | 52.33(46.34) | 50.83(45.48) | 1.74 | 2.05 | 207.00 | 48.17 (43.95) | 5.67 | 9.00 |
| 4 | ICP-990016 | 19.67 | 12.67 | 48.50(44.14) | 48.33(44.04) | 1.49 | 1.51 | 150.67 | 45.93 (42.66) | 5.00 | 8.67 |
| 5 | ENT-11 | 21.00 | 16.00 | 40.00(39.23) | 32.33(34.65) | 0.87 | 0.94 | 115.33 | 40.65 (39.59) | 4.00 | 7.33 |
| 6 | ICP-10531 | 18.67 | 12.50 | 46.00(42.70) | 43.67(41.36) | 1.40 | 1.31 | 151.67 | 44.25 (41.70) | 5.00 | 8.67 |
| 7 | ICP-13198 | 18.67 | 11.17 | 45.17(42.23) | 41.33(40.01) | 1.38 | 1.38 | 142.00 | 45.41 (42.36) | 5.00 | 8.33 |
| 8 | ICPHRL-4978-5 | 18.67 | 10.33 | 55.17(47.97) | 48.67(44.24) | 1.67 | 1.98 | 194.00 | 47.13 (43.35) | 6.33 | 9.00 |
| 9 | ICPHRL-4979-2 | 19.00 | 13.67 | 41.00(39.81) | 31.33(34.04) | 0.95 | 1.31 | 134.33 | 43.24 (41.11) | 4.33 | 8.00 |
| 10 | ICPHRL-4985-1 | 18.33 | 11.00 | 55.33(48.06) | 49.50(44.71) | 1.68 | 2.02 | 199.00 | 47.45 (43.54) | 6.00 | 9.00 |
| 11 | ICPHRL-4985-10 | 18.00 | 11.67 | 49.00(44.43) | 47.50(43.57) | 1.60 | 1.58 | 151.67 | 44.79 (42.01) | 5.67 | 8.67 |
| 12 | ICPHRL-4989-7 | 18.33 | 10.33 | 50.33(45.19) | 51.83(46.05) | 1.80 | 1.84 | 189.00 | 48.67 (44.24) | 7.00 | 9.00 |
| 13 | ICPL-20062 | 18.67 | 11.00 | 50.67(45.38) | 47.83(43.76) | 1.61 | 1.80 | 163.67 | 47.21 (43.40) | 5.67 | 8.67 |
| 14 | ICPL-332 (R) | 21.00 | 13.00 | 43.67(41.36) | 36.67(37.26) | 1.07 | 1.26 | 132.33 | 42.64 (40.76) | 4.33 | 8.33 |
| 15 | ICPL-909 | 20.00 | 11.83 | 46.00(42.70) | 43.33 (41.17) | 1.36 | 1.36 | 138.00 | 45.23 (42.26) | 5.00 | 9.00 |
| 16 | ICPL-97253 | 19.67 | 12.00 | 46.33(42.90) | 39.83(39.13) | 1.25 | 1.40 | 134.33 | 44.70 (41.96) | 5.00 | 8.67 |
| 17 | PPE-45-2 | 19.00 | 11.67 | 45.00(42.13) | 43.33(41.17) | 1.41 | 1.41 | 153.67 | 47.16 (43.36) | 5.00 | 8.67 |
| 18 | ICPL-87 (S) | 17.33 | 9.17 | 59.00(50.19) | 59.67(50.57) | 2.25 | 2.84 | 255.00 | 52.56 (46.47) | 7.00 | 10.33 |
| 19 | ICPL-87119 | 19.00 | 11.17 | 45.33(42.32) | 43.83(41.46) | 1.45 | 1.68 | 177.33 | 48.25 (43.99) | 6.00 | 8.67 |
| 20 | PKV-TARA | 19.00 | 11.67 | 50.83(45.48) | 44.33(41.75) | 1.44 | 1.64 | 176.00 | 49.77 (44.87) | 6.00 | 9.00 |
| 21 | AKT-8811 | 18.67 | 11.50 | 50.83(45.48) | 43.33(41.17) | 1.43 | 1.77 | 180.00 | 48.41 (44.09) | 5.67 | 9.33 |
| 22 | BSMR-736 | 17.67 | 10.00 | 55.33(48.06) | 48.00(43.85) | 1.73 | 2.66 | 236.33 | 51.66 (45.95) | 6.67 | 9.00 |
| 23 | ICPH-2671 | 18.67 | 10.50 | 48.50(44.14) | 45.33(42.32) | 1.55 | 1.76 | 166.00 | 46.98 (43.27) | 5.00 | 9.00 |
| 24 | ICPH-2740 | 19.00 | 11.67 | 53.50(47.01) | 45.33(42.32) | 1.47 | 1.75 | 193.00 | 47.86 (43.78) | 5.67 | 9.00 |
| S.Em. ± | | 0.76 | 0.357 | 0.90 | 1.53 | 0.02 | 0.06 | 6.69 | 1.38 | 0.38 | 0.55 |
| CD at 5% | | 2.03 | 0.96 | 2.41 | 4.09 | 0.06 | 0.17 | 17.94 | 3.71 | 1.03 | 1.48 |
| CV % | | 4.91 | 3.79 | 2.45 | 4.11 | 1.70 | 4.53 | 4.74 | 3.92 | 8.46 | 7.72 |

** Fingers in parentheses are arc sine transformed values

R-Resistant check, S-Susceptible check.

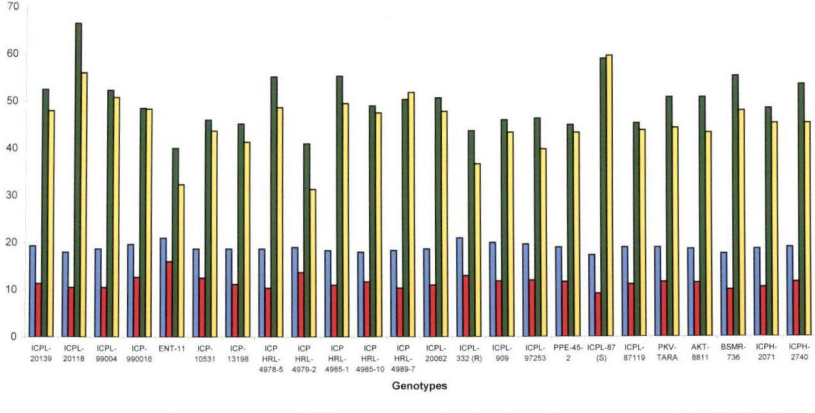



**Fig.10.Development of *H. armigera* larvae reared on flowers and pod of different pigeonpea genotypes**

*H. armigera* larvae fed with flowers and pods of genotype ENT-11 at 15 days after initiating the experiment recorded lowest average weight (248.33 mg) of full grown larva which was followed by ICPL-332 (250.67 mg), ICP-13198 (253.33 mg) and ICP-10531 (260 mg) in order and were statistically at par with each other and had significantly lower weight than the larva fed on other genotypes.

Moderate larval weight was recorded in ICPHRL-4979-2 (274.67 mg), ICPL-909 (281.67 mg) PPE-45-2 (282.33 mg), ICPL-20139 (290.67 mg), ICPHRL-4985-10 (293 mg), PKV-TARA (296 mg), ICPL-87119 (297.67 mg), ICPL-990016 (299.67 mg), ICPHRL-4985-1 (303 mg) and ICPH-2671 (308.67 mg) in their order.

Highest weight of 15 days old larva was gained by the pod borer reared on susceptible check ICPL-87 (363.33 mg) which was statistically at par with ICPL-20118 (357.33 mg) and ICPHRL-4978-5 (354.67 mg) and has significantly highest weight than the larva fed on rest genotypes.

The overall result on an antibiosis effect of pigeonpea genotypes on larval weight of *H. armigera* revealed that the genotype ENT-11, followed by ICPL-332, ICP-13198 and ICP-10531 recorded lowest larval weight and significantly superior over all genotypes. Susceptible Check ICPL-87 recorded highest larval weight and was statistically at par with the genotypes ICPL-20118 and ICPHRL-4978-5.

**iv) Pupal weight**

The data presented (Table-12 Fig.12) showed antibiosis effect on pupal weight. There were significant differences in the development of the pupa. Lowest pupal weight was observed in in ENT-11 (171.67 mg) which was at par with ICPHRL-4979-2, ICPL-233 (174.33 mg) and ICPL-20062 (192 mg) and statistically significant over remaining genotypes and showed highly adverse effect on pupal development. Another group, which revealed adverse effect on pupal weight was ICP-13198 (194.33 mg), PPE-45-2 (194.67 mg), ICP-10531 (197.67 mg), ICPL-909 (204.67 mg), ICPH-2671, ICP-990016 (205 mg), ICPL-97253 (207 mg), ICPH-2740, ICPL-87119 (212.33 mg) and PKV-TARA (213.33 mg) which were at par with each other and satistically significant over other germplasm. ICPL-87 recorded

highest pupal weight 280 mg which had significantly higher weight than remaining genotypes followed by ICPL-20118 (275.33 mg).

**Table 12. Larval and pupal weight of H. *armigera* (Hubner) reared on flowers and pod of different pigeonpea genotypes.**

| Sr. No | Genotype | Larval weight (mg) | | | Pupal weight. (mg) |
|---|---|---|---|---|---|
| | | day5$^{th}$ | day10$^{th}$ | day15$^{th}$ | |
| 1 | ICPL-20139 | 15.43 | 190.33 | 290.67 | 223.00 |
| 2 | ICPL-20118 | 20.03 | 205.67 | 357.33 | 275.33 |
| 3 | ICPL-99004 | 15.40 | 202.67 | 325.33 | 236.00 |
| 4 | ICP-990016 | 14.93 | 187.00 | 299.67 | 205.00 |
| 5 | ENT-11 | 14.67 | 173.00 | 248.33 | 171.67 |
| 6 | ICP-10531 | 15.03 | 181.67 | 260.00 | 197.67 |
| 7 | ICP-13198 | 14.20 | 172.00 | 253.33 | 194.33 |
| 8 | ICPHRL-4978-5 | 18.47 | 205.67 | 354.67 | 257.00 |
| 9 | ICPHRL-4979-2 | 14.70 | 187.33 | 274.67 | 174.33 |
| 10 | ICPHRL-4985-1 | 17.00 | 213.67 | 303.00 | 241.67 |
| 11 | ICPHRL-4985-10 | 15.83 | 178.33 | 293.00 | 217.00 |
| 12 | ICPHRL-4989-7 | 17.93 | 230.00 | 336.67 | 236.67 |
| 13 | ICPL-20062 | 18.13 | 178.00 | 324.00 | 192.00 |
| 14 | ICPL-332 (R) | 15.20 | 181.00 | 250.67 | 174.33 |
| 15 | ICPL-909 | 16.83 | 187.00 | 281.67 | 204.67 |
| 16 | ICPL-97253 | 15.33 | 192.00 | 320.33 | 207.00 |
| 17 | PPE-45-2 | 14.40 | 179.33 | 282.33 | 194.67 |
| 18 | ICPL-87 (S) | 19.23 | 235.67 | 363.33 | 280.00 |
| 19 | ICPL-87119 | 16.40 | 189.00 | 297.67 | 212.33 |
| 20 | PKV-TARA | 15.50 | 190.00 | 296.00 | 213.33 |
| 21 | AKT-8811 | 15.63 | 197.33 | 319.67 | 220.00 |
| 22 | BSMR-736 | 19.13 | 201.33 | 352.67 | 237.00 |
| 23 | ICPH-2671 | 16.77 | 195.67 | 308.67 | 205.00 |
| 24 | ICPH-2740 | 16.10 | 188.67 | 311.67 | 212.33 |
| **S.Em. ±** | | **0.36** | **5.48** | **6.60** | **7.70** |
| **CD at 5%** | | **0.97** | **14.69** | **17.70** | **20.64** |
| **CV %** | | **2.70** | **3.47** | **2.66** | **4.37** |

R-Resistant check, S-Susceptible check.

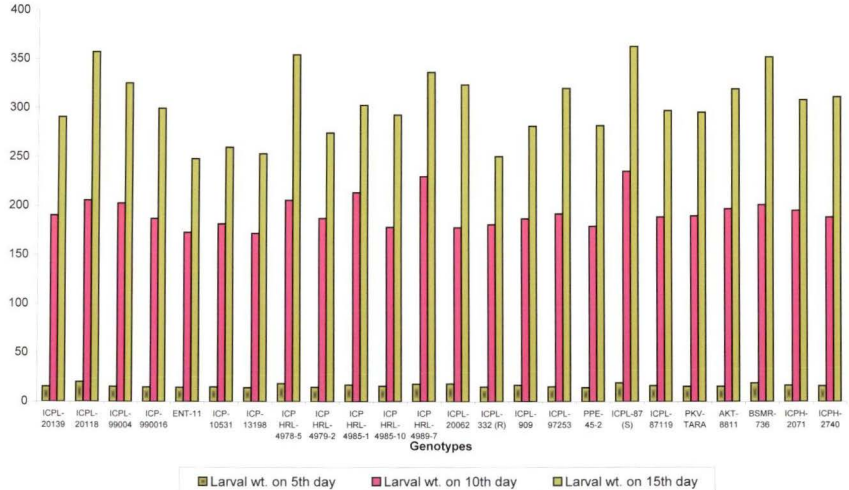



**Fig.11. Larval weight of *H. armigera* (Hubner) reared on flowers and pod of different pigeonpea genotypes**

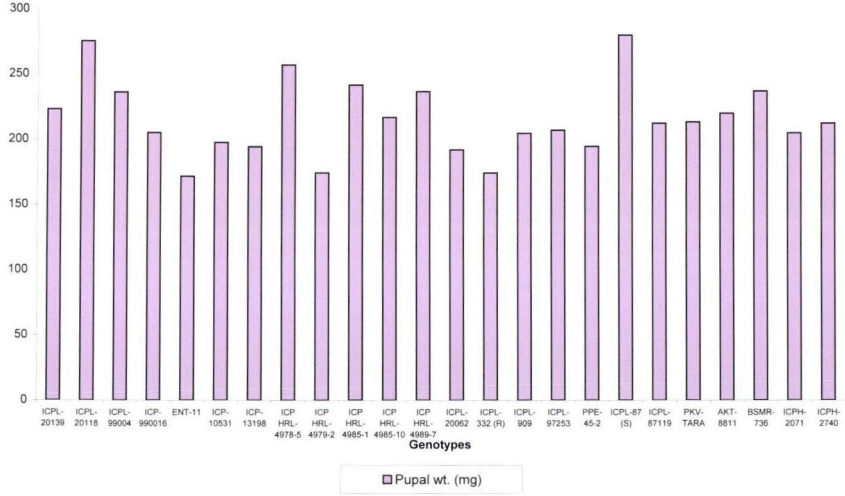



**Fig.12. Pupal weight of *H. armigera* (Hubner) reared on flowers and pod of different pigeonpea genotypes**

**v) Pupal period**

The data pertaining to the pupal period (Table11 Fig.10) revealed that maximum pupal period of 16 days was registered by the pest when reared on ENT-11 which was statistically significant over all genotypes. Former was followed by ICPHRL-4979-2 (13.67 days) and ICPL-332 (13 days) which were statistically at par with each other and significantly superior over remaining genotypes.Susceptible check ICPL-87 recorded 9.17 days pupal period and was at par with BSMR-736 (10 days).

**vi) Per cent pupation**

The data (Table-11, Fig.10) revealed that average per cent pupation was lowest when larvae of *H. armigera* reared on flowers and pods of genotype ENT-11 (40%), and was at par with ICPHRL-4979-2 (41%), ICPL-332 (43.67%) and had significantly lower pupation. The second group, which showed moderate adverse effect on per cent pupation of *H. armigera* larvae were PPE-45-2 (45%), ICP-13198 (45.17%), ICPL-87119 (45.33%), ICPL-909, ICP-10531(46.00%), ICPL-97253 (46.33%), ICPH-2671, ICP-990016 (48.50%), and ICPHRL- 4985-10 (49%) in their order and were at par with each other.

Maximum per cent pupation was recorded in genotype ICPL-20118 (66.50%) which was significantly highest than rest of the genotypes. However, ICPL-87 recorded 59 per cent pupation which was statistically at par with ICPHRL-4985-1, BSMR-736 (55.33%), and ICPHRL-4978-5 (55.17%).

**vii) Adult emergence**

The *H. armigera* larvae reared on flowers and pods of genotype ICPHRL-4979-2 recorded (Table-11, Fig.10) lowest adult emergence 31.33 per cent which was statistically at par with ENT-11 (32.33%) and were significantly superior over remaining treatments in terms of reduced per cent adult emergence. The genotypes ICPH-2740, ICPH-2671 (45.33%), ICPHRL-4985-10 (47.50%) and ICPL-20062 (47.83%) were in intermediate group and were at par with each other.

Maximum per cent adult emergence was recorded in genotype ICPL-87 (59.67%) followed by ICPL-20118 (56%) which were statistically at

par with each other. Thus, the susceptible genotypes always favoured the adult per cent emergence.

**viii) Growth Index**

Lowest growth index was registered in genotype ENT-11 (0.87) (Table-11, Fig.13). It was significantly lowest than rest of the genotypes. It was followed by the *H. armigera* reared on flowers and pods of ICPHARL-4979-2 (0.95). Highest growth index of *H. armigera* was noticed when it was fed with flowers and pods of susceptible genotype ICPL-87 (2.25) which was significantly higher than rest of the genotypes. Former was followed by ICPL-20118 (1.96) which was also significantly higher than remaining genotypes. Genotypes ICPHRL-4989-7 (1.80), ICPL-99004 (1.74) and BSMR-736 (1.73) had moderately higher growth index and favored the growth of the pest population.

**ix) Female /Male ratio**

Significantly lowest female /male ratio (Table-11, Fig 13) was noticed when *H. armigera* was reared on flowers and pods of genotype ENT-11 (0.94) and showed adverse effect on the population of pest. Former was followed by ICPL-332 (1.26) and was at par with each other.

Significantly highest female/male ratio was noticed when *H. armigera* reared on susceptible check ICPL-87 (2.84) followed by BMR-736 (2.66) and ICPL-20118 (2.47) which had significantly higher female/male ratio than remaining genotypes.

**x) Average fecundity/female**

*H. armigera* reared on flowers and pods of ENT-11 genotype (Table-11, Fig.14) laid on an average 115.33 eggs/female followed by ICPL-332 (132.33 eggs/female) and were statistically at par with each other and significantly lowest than rest of the treatments. The adult female from larva reared on susceptible check ICPL-87 registered significantly highest fecundity (255 eggs/female) than rest of the treatments. It was followed by ICPL-20118 and BSMR-736 (236.33).

**xi) Per cent hatchability**

Larva reared on flowers and pods of ENT-11 had lowest hatchability of eggs 40.65 per cent which was followed by ICPL-332 (42.64%). Borer reared on flowers and pods of ICPL-87 showed highest

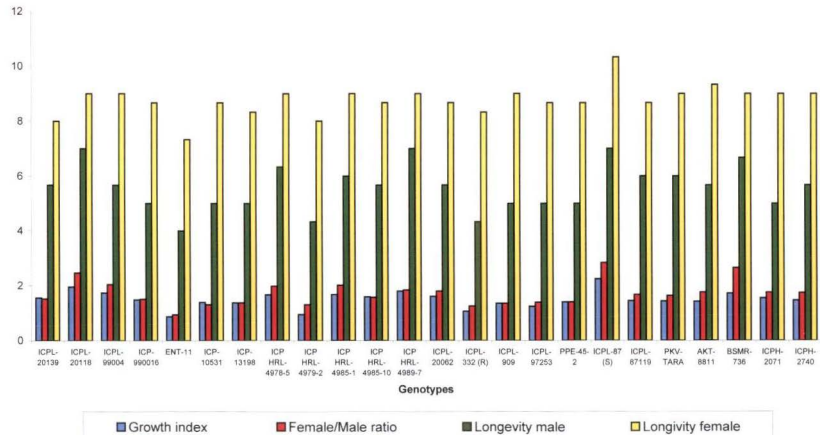



**Fig.13. Development of *H. armigera* larvae reared on flowers and pod at different pigeonpea genotypes.**

**ix) Female /Male ratio**

Significantly lowest female /male ratio (Table-11, Fig 13) was noticed when *H. armigera* was reared on flowers and pods of genotype ENT-11 (0.94) and showed adverse effect on the population of pest. Former was followed by ICPL-332 (1.26), ICPHRL-4979-2, ICP-10531 (1.31), ICPL-909 (1.36), ICP-13198 (1.38), ICPL-97253 (1.40) and PPE-45-2 (1.41) in their order and were statistically at par with each other. Moderate female/male ratio was noticed in genotypes PKV-TARA (1.64) followed by ICPL-87119 (1.68), ICPH-2740 (1.75), ICPH-2071 (1.76), AKT-1188 (1.77) and ICPL-20062 (1.8) in their order and at par with each other.

Significantly highest female/male ratio was noticed when *H. armigera* reared on susceptible check ICPL-87 (2.84) followed by BMR-736 (2.66) and ICPL-20118 (2.47) which had significantly higher female/male ratio than remaining genotypes.

**x) Average fecundity/female**

*H. armigera* reared on flowers and pods of ENT-11 genotype (Table-11,Fig.14) laid on an average 115.33 eggs/female followed by ICPL-332 (132.33 eggs/female) and were statistically at par with each other and significantly lowest than rest of the treatments. Former was followed by ICPL-97253, ICPHRL-4979-2 (134.33), ICP-909 (138), ICP13198 (142), ICP-990016 (150.67) and ICPHRL-4985-10 (151.67) in their order and were at par with each other. Moderate average fecundity per female was noticed in ICPL-20062 (163.67) followed by ICPH-2071 (166), ICPL-20139 (172), PKV-TARA (176), ICPL-87119 (177.33) and AKT-8811 (180) in their order and were at par with each other.( The larva reared on susceptible check ICPL-87 registered significantly highest fecundity (255 eggs/female) than rest of the treatments. It was followed by ICPL-20118 and BSMR-736 (236.33).

**xi) Per cent hatchability**

Larva reared on flowers and pods of ENT-11 had lowest hatchability of eggs 40.65 per cent which was followed by ICPL-332 (42.64%), ICPHRL-4979-2 (43.24%), ICP-10531(44.25%), ICPL-97253 (44.70%), ICPHRL-4985-10 (44.79%), ICPL-909 (45.23%), ICP-13198 (45.41%),ICP-990016 (45.93%) and ICPH-2071 (46.98%) in their order and

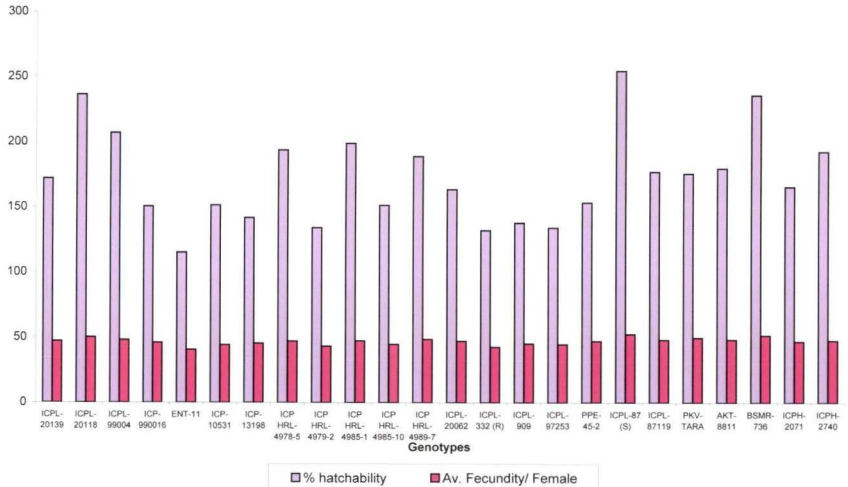
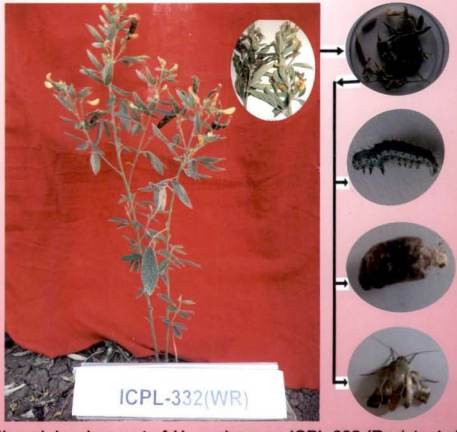



**Fig.14. Development of *H. armigera* larvae reared on flowers and pod at different pigeonpea genotypes.**


Growth and development of *H. armigera* on moderately resistant genotype ENT-11



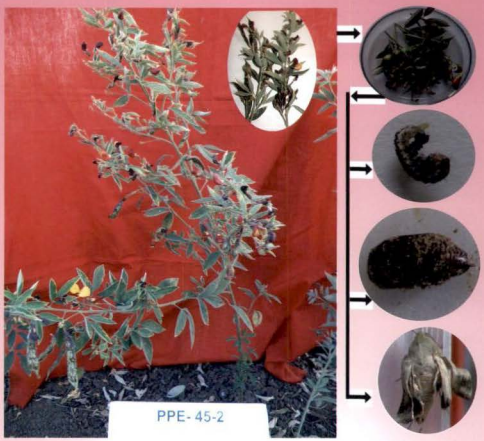

Growth and development of *H. armigera* on ICPL-332 (Resistant check)

**Plate 6. Promisisng moderately resitant genotypes of pigeonpea**


Growth and development of *H. armigera* on moderately resistant genotype ICPHRL-4979-2


Growth and development of *H. armigera* on moderately resistant genotype ICP-10531

**Plate 7. Promising moderately resistant genotypes of pigeonpea**




Growth and development of *H. armigera* on moderately resistant genotype PPE-45-2


Growth and development of *H. armigera* on moderately resistant genotype ICPL-97253

Plate 8. Promising moderately resistant genotype pigeonpea

hatchability of eggs 52.56 per cent which was followed by BSMR-736 (51.66%), ICPL-20118 (50.22%), PKV-TARA (49.77%) and ICPHRL-4989-7 (48.67%) (Table-11, Fig. 14).

**xii) Male longevity**

Longevity of adult male from larva reared on flowers and pods of ENT-11 was lowest (4 days) which was followed by ICPL-332. Whereas, the adult longevity in susceptible check ICPL-87 was longest (7 days) along with genotype ICPL-20118 and ICPHRL-4989-7(7 days)(Table-11, Fig.14).

**xiii) Female longevity**

Longevity of adult female from larva reared on flowers and pods of ENT-11 was lowest (7.33 days); while in susceptible check ICPL-87 genotype noticed longest longevity of 10.33 days which was followed by AKT-8811 (9.33 days). The remaining genotypes recorded longevity of 9 days (Table-11, Fig.12).

Expression of antibiosis to *H. armigera* varied significantly among the pigeonpea genotype tested (Plate 6, 7 and 8). Lower larval weights and prolonged post embryonic development were observed in adult female from larvae reared on flowers and pods of resistant pigeonpea genotypes, which could be due to poor nutritional quality of flowers and pods vis-à-vis due to high concentrations of secondary metabolites in the flowers and pods of resistant genotypes. Compared to the susceptible check ICPL-87 the larval and pupal weights of *H. armigera* were significantly lower when larvae reared on flowers and pods of ENT-11 and resistant check ICPL-332, ICPHRL-4979-2, ICP-10531, ICP-13198, PPE-45-2 ICPL-909, ICPL-97253, ICP-990016 and ICPL-20062. Similarly larval and pupal periods were also prolonged significantly in insects, indicating antibiosis to *H. armigera* in these genotypes of pigeonpea.

The effects of antibiosis are also expressed in terms of weight and size of insects, sex ratio and proportion of insects entering into diapauses (Dhandapani and Balasubramanian, 1980). Dodia and Patel (1994) reported that significant decline in the larval and pupal weights and longer duration in both the stages were observed for larvae fed on developing pods of resistant varieties, ICPL-270 and ICPl-84060 as compared to fed on the susceptible variety BDN-2.

Sison and Shanower (1994) observed that the larvae of *H. armigera* reared on ICPL-86012 had the lowest larval weight and longest larval period. Wheareas, those reared on ICPL-86005 had the lowest pupal weight and longer pupal period among the short-duration genotypes of pigeonpea. Larvae reared on ICPL-87 had the shortest larval time, the highest larval and pupal weights, and longest adult lifespan. Larval and pupal weights were significantly higher, larval developmental period was significantly shorter and adult lifespan significantly longer when larvae were reared on pods compared with flowers or leaves.

Dodia et al. (1996) found that larval and pupal development period and pupal length were adversely affected when fed on flowers of wild relatives of pigeonpea. Growth index and fecundity were also adversely affected in the larvae reared on wild species and their $F_1$. The adult emerging from larvae reared on wild species were smaller than the adults which emerged from cultivated pigeonpea. Shanower et al. (1997) revealed that larval mortality and prolongation of larval period were the main componants of resistance to *H. armigera* in the pigeonpea.

Sujana et al. (2008) evaluated wild relatives of pigeonpea for antibiosis components of resistance to *H. armigera*. High levels of antibiosis were observed when the larvae were reared on leaves and /or pods. Post-embryonic development period was prolonged in insects reared on resistant genotypes.

Anitha Kumari et al. (2010) observed that Incorporation of 10g of lyophilized leaves or pods into the artificial diet (300 ml) of diet resulted in maximum differences in survival and development of *H. armigera* larvae on the resistant (ICPL-332) and susceptible (ICPL-87) genotypes. Reduced larval and pupal weight and prolongation of larval and pupal development periods were observed on in insects reared on intact leaves or pods of ICPL-332, ICPL-84060, ICP-7035, ICPL-88039 and T-21. Similar effects were also observed in larvae reared on artificial diet impregnated with lyophilized leaves or pods of ICPL-332, ICPL-84060, ICP-7035, ICPL-187-1, ICPL-88039 and ICP-7203-1. Larval and pupal periods, pupal weight, and pupation and adult emergence were positively correlated between the insects reared on fresh leaves or pods, and on artificial diets impregnated

with lyophilized leaves or pods. From the foregoing findings and supporting literatures it can be inferred that resistant / moderately resistant genotypes of pigeonpea affected adversely on the growth and development of *H. armigera*. Whereas,susceptible genotypes favoured the growth and development and overall biology of *H. armigera* (Plate 9).

**4.3.5 Tolerance**

Tolerence to *H. armigera* was studied in pigeonpea genotypes under unprotected condition in the field. The pooled data obtained from screening during 2011 and 2012 (Table-13, Fig.15) was used in this study for interpretation. Tolerance mechanism of resistance was identified in 24 genotypes on the basis of per cent pod damage and their relative yield performance.

**4.3.5.1 Per cent pod damage**

The pooled mean of per cent pod damage of both the trials ranged between 5.97 to 26.08 per cent (Table-13, Fig.15). Significantly, lowest per cent pod damage was recorded in ENT-11 (5.97%) followed by ICPL-332 (9.75%) which was at par with former.The maximum per cent pod damage was observed in ICPL-87 susceptible check (26.08%) followed by BSMR-736 (22.92%) and ICPHRL-4978-5 (22.50%).

**4.3.5.2 Grain yield**

Data on grain yield q/ha obtained from different genotypes of pigeonpea (Table-13, Fig.15) indicated that PKV-TARA recorded highest yield (17.69q/ha).Lowest yield was recorded in ENT-11 (6.84q/ha). However, ENT-11 showed poor performance in recording yield though it was found resistant to *H. armigera*. Next in lower yield was ICPL-87 (7.66q/ha) followed by ICPL-99004 (7.98q/ha) and ICPL-20118 (9.36q/ha).

The data revealed that the genotype PKV-TARA had pod damage of 19.68% followed by ICPL-20062 (18.75%), AKT-8811 (18.12%), and ICPL-87119 (17.25%) and ICPH-2740 (17.33%) which is comparatively more infestation than resistant check ICPL-332 (9.75%), ICPHRL-4979-2 (13.08%) and ICPL-97253 (13.90%). Nevertheless, these genotypes showed more tolerance to the attack of *H. armigera* and withstood the attack by recording more grain yield in PKV-TARA (17.69


Plate 9. Growth and development of H. armigera on susceptible check ICPL-87

q/ha), AKT-8811 (16.10 q/ha), ICPL-87119 (16.72 q/ha) and ICPL-20062 (14.58 q/ha) and ICPH-2740 (14.61 q/ha) compared to the rest of the pigeonpea genotypes (Plate 10).

**Table 13. Relative infestation and yields of different genotypes of pigeonpea**

| Sr. No | Genotype | Pooled Mean (%) infestation | Pooled Mean yield qt/ ha |
|---|---|---|---|
| 1 | ICPL-20139 | 17.28(4.12) | 14.74 |
| 2 | ICPL-20118 | 22.08(4.70) | 9.36 |
| 3 | ICPL-99004 | 21.58(4.65) | 7.98 |
| 4 | ICP-990016 | 14.42(3.81) | 14.56 |
| 5 | ENT-11 | 5.97(2.42) | 6.84 |
| 6 | ICP-10531 | 14.42(3.81) | 15.18 |
| 7 | ICP-13198 | 14.87(3.84) | 16.10 |
| 8 | ICPHARL-4978-5 | 22.50(4.71) | 9.46 |
| 9 | ICPHARL-4979-2 | 13.08(3.61) | 14.56 |
| 10 | ICPHARL-4985-1 | 21.18(4.60) | 11.11 |
| 11 | ICPHARL-4985-10 | 16.95(4.08) | 12.19 |
| 12 | ICPHARL-4989-7 | 21.75(4.66) | 11.47 |
| 13 | ICPL-20062 | 18.75(4.32) | 14.58 |
| 14 | ICPL-332 (R) | 9.75(3.11) | 15.56 |
| 15 | ICPL-909 | 13.92(3.72) | 16.02 |
| 16 | ICPL-97253 | 13.90(3.72) | 16.92 |
| 17 | PPE-45-2 | 14.08(3.75) | 16.62 |
| 18 | ICPL-87 (S) | 26.08(5.10) | 7.66 |
| 19 | ICPL-87119 | 17.25(4.11) | 16.72 |
| 20 | PKV-TARA | 19.68(4.42) | 17.69 |
| 21 | AKT-8811 | 18.12(4.26) | 16.10 |
| 22 | BSMR-736 | 22.92(4.78) | 12.91 |
| 23 | ICPH-2671 | 17.82(4.20) | 14.03 |
| 24 | ICPH-2740 | 17.33(4.13) | 14.61 |
| **S.Em. ±** | | **0.26** | **0.93** |
| **CD at 5%** | | **0.75** | **2.64** |
| **CV %** | | **11.09** | **11.92** |

Figures in parentheses are square root transformed values.

R-Resistant check, S-Susceptible check.

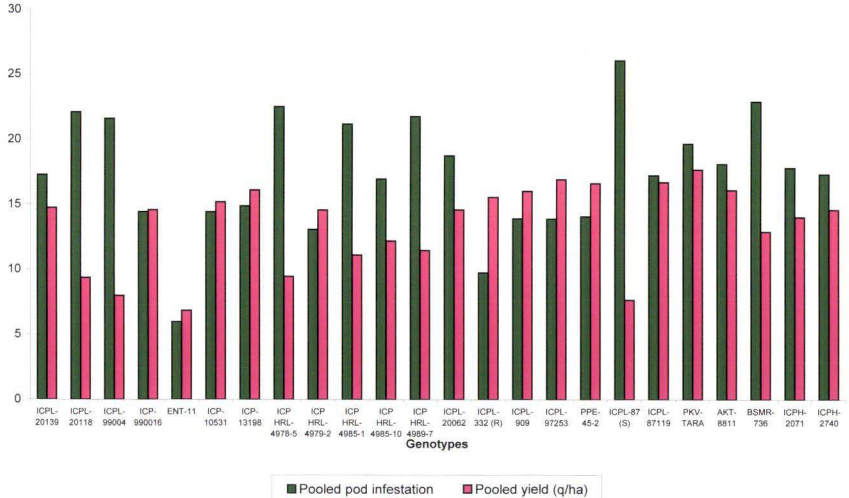



**Fig.15. Pooled pod infestation and yield of different pigeonpea genotypes**


AKT - 8811


ICPH-2740


ICPL-87119


PKV-TARA


ICPL -20062

**Plate 10. Promising tolerant genotypes of pigeonpea**

The genotype ENT-11 had lowest pod damage of 5.97 per cent but comparatively grain yield was poor (6.84 q/ha). Thus, this genotype showed resistance but noted as poor yielder exceptionally. It might be due to genetic characters of this particular genotype.

The overall results from the data (Table 13 and Fig.15) indicated that some of the genotypes which had high damage, but in spite of this could withstand the attack by *H. armigera* and compensated to attack and yielded more by expressing tolerance mechanism.

These observations were similar to the findings of Tingey (1981), who reported that effect 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, nutrient and growth regulation and partitions. Lateef and Pimbert (1990) reported that among the medium duration genotype most of the genotypes had intermediate growth habitat, and genotypes ICP- 909, PPE- 45-2, ICP-1811- EB, ICP- 1903- E, ICPL- 332 and ICP- 10466- E3 had shown less susceptibility to pod borer.

Mali and Patil (1994) observed T-21 as least infested by pod borer. Patel et al. (1994), studied field screening of pigeonpea genotypes against pod borer. They found among seven genotypes, GAUT-82-90 was the least susceptible genotype to all three insect pests, i.e. *H. armigera* and other pest with the highest yield potentials. Minja et al., (1999) also reported the tolerance to pod borer in pigeonpea at ICRISAT.

The genotypes screened during the present investigations, some of them had shown tolerance mechanism of resistance viz., PKV-TARA, AKT-8811, ICPL-87119, ICPL-20062 and ICPH-2740 had some what more damage, nevertheless these genotypes yielded more comparatively than rest of the genotypes. However, the tolerance of these genotypes could not be discussed due to paucity of literature on these genotypes.

### 4.4 Bio-physical basis of resistance

#### 4.4.1 Trichome types and their density in 24 genotypes

Studies were conducted on bio-physical components associated with resistance to *H. armigera*. Data were recorded on trichomes, the hairy

structures, on flowers (calyx) and pods is presented in Table 14 and depicted in Fig.16.

Trichomes, the hairy out growths, were observed on the calyxes and pod wall surfaces. The calyx and pod wall surfaces were scanned under a Compound microscope (40x). Four morphologically distinct types of trichomes (Type A-D) (Plate 11 and 12) were identified from calyx and pods. Type A and type B were glandular trichomes, whereas, type C and type D were non glandular trichomes. The type A trichome had a long tubular neck with 4 to 8 cells, and an enlarged base. It secretes clear exudates visible as droplets at the top and along the shaft of the trichome. Type B trichome was a sac like structure containing yellow, oily substance. The secretions in the type B trichomes were liberated only when the cell wall is ruptured. Type C and type D trichomes were unsegmented and nonglandular. The type C trichome was short and type D trichome was generally 4 to 11 times longer than type C trichome. Density and distribution of different types of trichomes varied significantly in different genotypes of pigeonpea.

### 4.4.2 Trichomes on calyx

#### 4.4.2.1 Type A

The density and distribution of trichomes; type A, type B, type C and type D varied significantly on the calyxes among the genotypes. Highest density of type A trichomes (Table-14, Fig.16) was observed on the calyx of ICPL-909 (26) followed by PPE-45-2 (24.33), ICPL99004 (24), ICPHRL-4985-1 (24), AKT-8811 (24), BSMR-736 (23.67), ICP-990016, ICPHRL-4978-5, ICPL-87 and ICPH-2740 (23) and these were at par with each other followed by ICPL-20118, ICP-10531 and ICPH-2671 (22), ICPL20139, ICPHRL-4985-10, and ICPHRL-4989-7 (21) in their order and at par with each other. The lowest density of type A trichome on calyx was observed in genotype PPE-45-2 and ICPL-332 (14.33) which were at par with ENT-11 (16), PKV-TARA and ICPL-20062 (17), and ICPL-87119 and ICPHRL-4979-2 (17.67).

**Table 14. Mean density of four different types of trichomes on calyx of different pigeonpea genotypes.**

| Sr. No | Genotype | Trichome type | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| 1 | ICPL-20139 | 21.00 | 5.33 | 52.00 | 44.00 |
| 2 | ICPL-20118 | 22.00 | 3.33 | 43.00 | 30.33 |
| 3 | ICPL-99004 | 24.00 | 2.67 | 49.00 | 31.33 |
| 4 | ICP-990016 | 23.00 | 0.33 | 58.33 | 47.00 |
| 5 | ENT-11 | 16.00 | 2.33 | 68.67 | 46.00 |
| 6 | ICP-10531 | 22.00 | 3.33 | 56.00 | 41.00 |
| 7 | ICP-13198 | 19.00 | 7.33 | 59.00 | 41.33 |
| 8 | ICPHRL-4978-5 | 23.00 | 6.33 | 56.00 | 28.00 |
| 9 | ICPHRL-4979-2 | 17.67 | 5.67 | 59.67 | 44.00 |
| 10 | ICPHRL-4985-1 | 24.00 | 6.67 | 49.00 | 33.00 |
| 11 | ICPHRL-4985-10 | 21.00 | 5.33 | 53.00 | 39.67 |
| 12 | ICPHRL-4989-7 | 21.00 | 2.00 | 48.00 | 29.00 |
| 13 | ICPL-20062 | 17.00 | 9.33 | 60.33 | 31.00 |
| 14 | ICPL-332 (R) | 14.33 | 10.00 | 57.00 | 36.33 |
| 15 | ICPL-909 | 26.00 | 10.00 | 53.00 | 45.00 |
| 16 | ICPL-97253 | 24.33 | 10.00 | 57.33 | 48.67 |
| 17 | PPE-45-2 | 14.33 | 2.33 | 57.00 | 44.33 |
| 18 | ICPL-87(S) | 23.00 | 12.00 | 51.00 | 39.00 |
| 19 | ICPL-87119 | 17.67 | 11.33 | 61.00 | 20.00 |
| 20 | PKV-TARA | 17.00 | 8.33 | 39.00 | 19.00 |
| 21 | AKT-8811 | 24.00 | 9.00 | 49.00 | 36.00 |
| 22 | BSMR-736 | 23.67 | 6.00 | 44.00 | 30.33 |
| 23 | ICPH-2671 | 22.00 | 6.67 | 51.67 | 32.00 |
| 24 | ICPH-2740 | 23.00 | 6.67 | 39.00 | 36.00 |
| **S.Em. ±** | | **1.26** | **0.57** | **1.94** | **2.18** |
| **CD at 5%** | | **3.37** | **1.53** | **5.19** | **5.85** |
| **CV %** | | **7.40** | **10.98** | **4.48** | **7.35** |

R-Resistant check, S-Susceptible check.

**4.4.2.2 Type B**

The number of type B trichomes on calyx was lower compared to other types of trichomes in all genotypes. Density of type B trichomes on calyx of different genotypes revealed significant differences. ICPL-87 recorded highest trichome density 12.00 per microscopic field on calyx and which was at par with ICPL-87119 (11.33) followed by ICPL-332, ICPL-909 and ICPL-97253 (10.00). Next group of genotypes ICPL-20062 (9.33) followed by AKT-8811 (9.00) and PKV-TARA (8.33) which was at par with each other. Group which recorded moderate density of type B trichomes

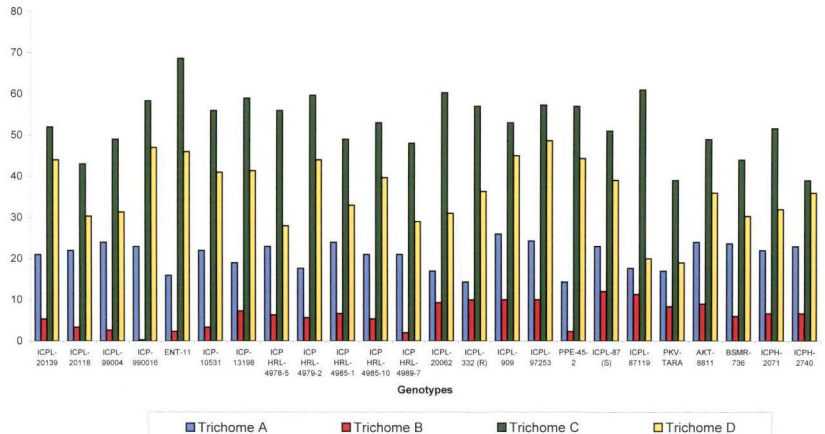
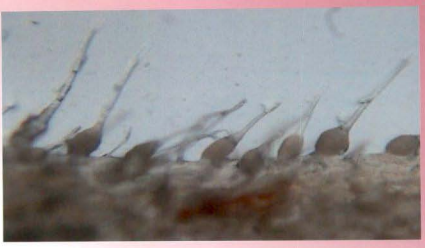
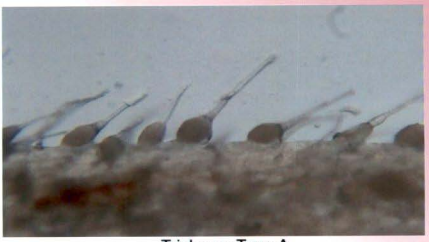
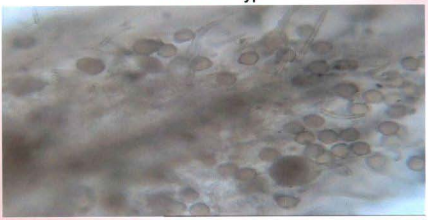



**Fig.16. Mean density of four different types of trichomes on calyx of different pigeonpea genotypes.**





Trichome Type A



Trichome Type B

Plate 11. Glandular Trichomes on Calyx of pigeonpea

was ICP-13189 (7.33) followed by ICPHRL-4985-1, ICPH-2671 and ICPH-2740 (6.67) which was at par with each other. Significantly low density of type B trichomes was noticed in ICP-990016 (0.33). It was followed by ICPHRL-4989-7 (2.00), PPE-45-2 and ENT-11(2.33), ICPL-99004 (2.67), ICP-10531 and ICPL-20118 (3.33) and was at par with each other.

**4.4.2.3 Type C**

ENT-11 recorded significantly highest density 68.67 of trichomes type C on per microscopic field of calyx, followed by ICPL-87119 (61.00), ICPL-20062 (60.33), ICPHRL-4979-2 (59.67), ICP-13198 (59.00), ICP-990016 (58.33), ICPL-97253 (57.33), ICPL-332 and PPE-45-2 (57.00), ICP-10531 and ICPHRL-4978-5 (56.00), which were at par with each other. Followed by ICPHRL-4985-10 and ICPL-909 (53.00), ICPL-20139 (52.00) and ICPH-2671 (51.67) which were at par with susceptible check ICPL87 (51.00). Next group of genotype showed lower and significantly inferior density than susceptible check, were ICPH-2740 and PKV-TARA (39.00) followed by ICPL-20118(43.00) and BSMR-736 (44.00) which was at par with each other.

**4.4.2.4 Type D**

There were significant differences in density of type D trichome between the genotype tested. Significantly higher number of trichomes were recorded in ICPL-97253 (48.67) trichomes/microscopic field on calyx which was at par with ICP-990016 (47.00), ENT-11(46), ICPL-909 (45.00), PPE-45-2 (44.33) ICPL-20139 and ICPHRL-4979-2(44) followed by ICP-13198 (41.33), ICP-10531 (41.00) ICPHRL-4985-10 (39.67), ICPL-87 (39.00) ICPL-332 (36.33), AKT-8811 (36.00) and ICPH-2740 (36.00) in their order. Next group which record showed lower trichome density includes ICPHRL-4985-1 (33.00) followed by ICPH-2671 (32.00), ICPL-99004 (31.33), ICPL-20062 (31.00) and BSMR-736 (30.33), ICPHRL-4989-7 (29.00) and ICPHRL-4978-5 (28.00) in their order and was at par with each other. Significantly low type D trichome density per microscopic field on calyx was recorded in PKV-TARA (19.00) which was at par with ICPL-87119 (20.00).

### 4.4.3 Trichomes on pods

#### 4.4.3.1 Type A

Four types of trichomes; type A, type B, type C and type D were observed on pods of all genotype tested. Density of different trichomes on pods was studied in all genotypes (Table-15, Fig.17). Significantly higher density of type A trichome was observed on the pods of ICPL-87 (49). It was followed by ICP-10531 (44), ICPL-909 (41) and ENT-11 (40.67) and was at par with each other. The next group genotypes which includes ICPHRL-4979-2 (39.67) followed by ICPL-97253 (39.33), ICP-990016 and ICP13198 (39), ICPHRL-4989-7 and PPE-45-2 (38.67) ICPL-20118 (38.33), ICPHRL-4978-5 (37), ICPHRL-4985-10 and resistant check ICPL-332 (36.33) in their order and was at par with each other. Lowest density of type A trichome 23.00 was observed in BSMR-736 which was followed by ICPL-99004 (23.67), PKV-TARA (24.33), AKT-8811 (26) and ICPH-2671 (28).

#### 4.4.3.2 Type B

Density of type B trichomes on pods of different genotypes revealed significant differences. BSMR-736 recorded highest trichome density of 10.00 per microscopic field on pod and which was at par with ICPH-2671 (9.67), ICPL-87119 (9) and ICPH-2740 (8.67). It was followed by ICPHRL-4985-10 and PKV-TARA (8.33), ICPHRL-4989-7 and susceptible check ICPL-87 (7.76) in their order and at par with each other. It was followed by ICP-990016 (6.67), ICPL-99004, ICPHRL-4985-1, and PPE-45-2 (6.33) in their order and was at par with each other. Group which recorded lower trichome density was ICP-10531 (1.33) followed by ICPHRL-4978-5 (1.67) resistant check ICPL-332 (2.33), AKT-8811, ICPL-97253, ICPL-909, ICP-113198, and ICPL-20118 (3.33) and ENT-11 (4.33).

#### 4.4.3.3 Type C

ENT-11 was recorded highest density, 76.33 of trichomes type C on per microscopic field of pod, followed by PPE-45-2 (73.33) and ICPHRL-4979-2 (72.00) and was at par with each other. It was followed byICPL-97253 (69.33), ICPL-909 and susceptible check ICPL-87 (68.67), ICP-990016 (67.67) and ICP-13198 (66.67) in their order and was at par with

each other. Next group recorded moderate density of trichomes were ICPHRL-4985-10 (62.33), ICP-10531 59.33) followed by ICPL-20139 and ICPL-20062 (58.67), ICPL-87119 (57.33), resistant check ICPL-332 (56.67), ICPHRL-4989-7 and PKV-TARA (56.33), ICPHRL-4985-10 (56), AKT-8811(55.33) and ICPHRL-4978-5 (55.00) in their order. Lowest density of trichme was recorded in ICPL-20118 (46.67) which was at par with BSMR-736 (47.33), ICPH-2671 (49.67), ICPL-99004 (51) and ICPH-2740 (51.33).

**Table 15. Mean density per microscopic field of four different types of trichomes on pods of different pigeonpea genotypes.**

| Sr. No | Genotype | Trichome type | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| 1 | ICPL-20139 | 30.00 | 6.33 | 58.67 | 32.33 |
| 2 | ICPL-20118 | 38.33 | 3.33 | 46.67 | 26.00 |
| 3 | ICPL-99004 | 23.67 | 6.33 | 51.00 | 28.00 |
| 4 | ICP-990016 | 39.00 | 6.67 | 67.67 | 39.67 |
| 5 | ENT-11 | 40.67 | 4.33 | 76.33 | 46.33 |
| 6 | ICP-10531 | 44.00 | 1.33 | 59.33 | 58.33 |
| 7 | ICP-13198 | 39.00 | 3.33 | 66.67 | 42.33 |
| 8 | ICPHRL-4978-5 | 37.00 | 1.67 | 55.00 | 52.00 |
| 9 | ICPHRL-4979-2 | 39.67 | 5.00 | 72.00 | 44.33 |
| 10 | ICPHRL-4985-1 | 32.00 | 6.33 | 56.00 | 48.00 |
| 11 | ICPHRL-4985-10 | 36.33 | 8.33 | 62.33 | 31.67 |
| 12 | ICPHRL-4989-7 | 38.67 | 7.67 | 56.33 | 51.67 |
| 13 | ICPL-20062 | 32.00 | 5.67 | 58.67 | 43.33 |
| 14 | ICPL-332 (R) | 36.33 | 2.33 | 56.67 | 33.67 |
| 15 | ICPL-909 | 41.00 | 3.33 | 68.67 | 30.33 |
| 16 | ICPL-97253 | 39.33 | 3.33 | 69.33 | 41.33 |
| 17 | PPE-45-2 | 38.67 | 6.33 | 73.33 | 46.67 |
| 18 | ICPL-87 (S) | 49.00 | 7.67 | 68.67 | 55.33 |
| 19 | ICPL-87119 | 28.00 | 9.00 | 57.33 | 35.33 |
| 20 | PKV-TARA | 24.33 | 8.33 | 56.33 | 36.67 |
| 21 | AKT-8811 | 26.00 | 3.33 | 55.33 | 31.67 |
| 22 | BSMR-736 | 23.00 | 10.00 | 47.33 | 23.00 |
| 23 | ICPH-2671 | 28.00 | 9.67 | 49.67 | 33.00 |
| 24 | ICPH-2740 | 31.00 | 8.67 | 51.33 | 31.33 |
| **S.Em. ±** | | **1.44** | **0.60** | **1.91** | **1.43** |
| **CD at 5%** | | **3.85** | **1.61** | **5.11** | **3.84** |
| **CV %** | | **5.06** | **12.77** | **3.89** | **4.47** |

R-Resistant check, S-Susceptible check.

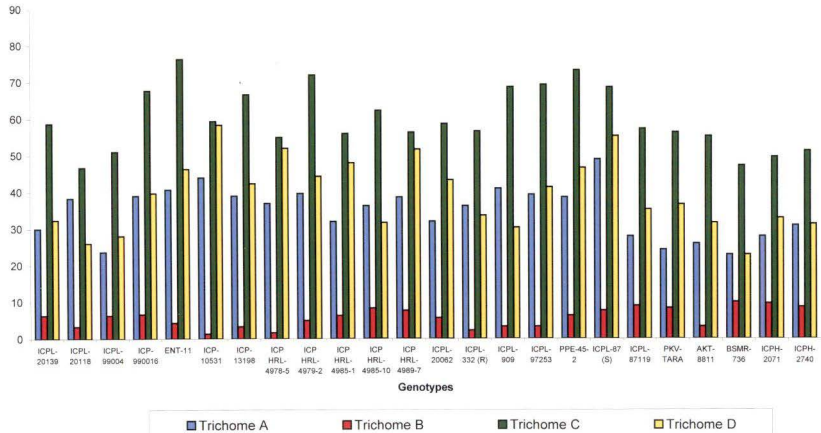
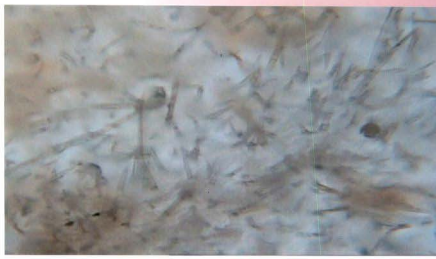



**Fig.17. Mean density of four different types of trichomes on pods of different pigeonpea genotypes.**



Trichome Type C

Trichome Type D

**Plate 12. Non glandular Trichomes on Calyx of pigeonpea**

#### 4.4.3.4 Type D

There were significant differences in the density of type D trichome between the genotypes. Higher number of trichomes was recorded in ICP-10531 (58.33) and ICPL-87 *i.e* 55.33 trichomes / microscopic field on pods which was at par with ICPHRL-4978-5 (52.00) and ICPHRL-4989-7 (51.67). Genotype ICPHRL-4985-1 recorded trichome density of 48.00 trichomes per microscopic field which was followed by PPE-45-2 (46.67), ENT-11 (46.33) and ICPHRL-4979-2 (44.33) in their order and was at par with each other. Next group of genotypes recorded trchome density of ICPL-20062 (43.33) followed by ICP-13198 (42.33), ICPL-97253 (41.33), ICP-990016 (39.67) and PKV-TARA (36.67) in their order and was at par with each other. Significantly lowest density of trichome was recorded in BSMR-736 (23.00) followed by ICPL-20118 (26.00) and ICPL99004 (28.00).

### 4.4.4 Correlation coefficients of trichomes with oviposition and per cent damage

**Table 16. Correlation of trichomes with oviposition and per cent damage**

| Trichome types | Oviposition | %damage |
|---|---|---|
| Trichome type A on pod | 0.415* | 0.424* |
| Trichome type B on pod | 0.042 | 0.194 |
| Trichome type C on pod | -0.487* | -0.419* |
| Trichome type D on pod | -0.433* | -0.489* |
| Total Trichome on Pod | -0.494* | -0.443* |
| Trichome type A on calyx | 0.411* | 0.484* |
| Trichome type B on calyx | 0.040 | -0.372 |
| Trichome type C on calyx | -0.496* | -0.504* |
| Trichome type D on calyx | -0.467* | -0.416* |
| Total Trichome on calyx | -0.430* | -0.507* |

* Significant at 5% ** Significant at 1% NS – Non-Significant

A significant and positive correlation was observed between the numbers of eggs laid (r=0.415) per cent pod damage (r=0.424) and the

density of glandular (type A) trichomes on calyxes and pods of tested genotypes. Numbers of eggs laid, per cent pod damage were significantly and negatively correlated with the density of non-glandular (type C) (r= -0.487 and r= -0.419) and (type D)(r= -0.433 and r = -0.489) trichomes. Type B, trichomes showed no association (r=0.042 and r=0.194) with egg laying, larval abundance, and pod damage (Table-16).

Trichomes play an important role in host resistance to insects Levin (1973). Bisen and Sheldrake (1981) reported three types of trichomes in *C. Cajan* viz., Simple nonglandular, yellow glandular sacs and tubular trichomes and suggested that glandular trichomes are source of the characteristic fragrance of pigeonpea. Southwood (1986) reported that variation in forms and functions of trichomes within the same species was the basis of plant resistance to insect attack. Zalucky et al. (1986) observed that under natural conditions, the pod borer females prefer to lay eggs on host plant during flowering stage, which could be due to an increase in chemical attractiveness of the crop.

David and Easwaramoorthy (1988), Peter (1995) also observed trichome types, their orientation, density and length influence host plant resistance/ susceptibility to insect pests. Glandular trichomes and their exudates act as an important mechanism to insects owing to the compounds exuded by them. Hartlieb and Rembold (1996) suggested that glandular-secretions from trichomes in pigeonpea acted as attractants to the adults of *H. armigera*.

Shanower et al. (1997) observed five types of trichomes viz; Type A, Type B, Type C, Type D and type E on pods of *Cajanus cajan* species and reported their importance in mechanism of resistance against *H. armigera*. The nongladular 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 time to develop and also have reduced larval growth and increased larval development period, resulting in lower pupal weight and low fecundity of *H. armigera*.

Romeis et al. (1999) reported dense nonglandular trichomes on pods of pigeonpea act as a physical barrier to young *H. armigera* larvae, while the glandular trichomes act as attractants to adult moths. Valverde et al. (2001) reported that nonglandular trichomes usually have hooked tips, which trap the insect, impede the insect activity by holding the insect and disallowing a contact with foliar surface, leading to starvation. Trichomes affect the physiology of insect by interfering with its digestion.

Rupakula Aruna et al. (2005) observed that resistance to pod borer and trichomes associated with it (low density of type A trichome and high density of type C). Sharma et al. (2009) reported that glandular trichomes (type A) on the calyxes and pods were associated with susceptibility to *H. armigera*, while the non-glandular trichomes (trichome type C and D) were associated with resistance to this insect.

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

The pod borer *H. armigera* lays more than 80 per cent of its eggs on pods and calyxes (Romeis, 1997). High density of nonglandular trichomes (type C and type D) might contribute to the larval mortality in the resistant genotypes ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE45-2, ICP-13198, ICPL-97253, ICP-990016 and ICPL-20062 although the cause and effect relationships need 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 biotic factors. Thus, the present results are in the tune to the findings of the previous workers pertaining to the trichome density.

### 4.5 Biochemical basis of resistance

Various biochemicals in flowers and pods of pigeonpea genotypes imparting resistance/ susceptibility to *H. armigera* (Table 17 Fig.17) were estimated and described as below.

#### 4.5.1 Crude protein

The protein content in flowers and pods of the pigeonpea genotypes tested differed significantly (Table-17 Fig.18). Highest quantity of protein content was observed in ICPHRL-4985-1 (17.63%) and was significantly superior over all remaining genotypes. Genotype ICPHRL-4989-7 recorded 16.47 per cent of crude protein which was followed by susceptible check ICPL-87 (16.17%) and ICPL-20118 (16.00%) which was at par with each other. Next group comprised of ICPL-99004 (15.87%), ICPHRL-4985-10 (15.50%) and ICPL-4978-5(15.45%) and were at par with each other. Moderate per cent of protein was noticed in ICPL-20139 and PKV-TARA (15.07%) followed by AKT-8811 (14.80%), ICPL-87119 (14.73%), ICPL-97253 (14.57%) and ICPH-2740 (14.50%) in their order and was statistically at par with each other.

Lowest quantity of protein was observed in genotype ENT-11-4978-5 (13.47%) which was followed by resistant check ICPL-332 (13.70%), ICPHRL-4979-2 (13.73%), ICP-10531 (13.80%) and ICPL-99004 (13.90%) in their order and was at par with each other. Low quantity of were also observed in ICP-990016 (14.03%) followed by PPE-45-2 (14.27%), ICPL-20062 (14.30%), ICP-13198 (14.43%) and ICPH-2671 (14.47%) in their order and was statistically at with each other.

The findings of the present investigation pertaining to crude protein is supported by the previous workers *viz*, Salunkhe et al. (1986) revealed that the protein content of commonly grown pigeonpea cultivars ranged between 17.9 to 24.3 g/100g. *H. armigera* preferred high protein in reproductive and growing plant parts which causes to serious losses in crop (Fitt,1989). Concentration of carbohydrate and protein and their ratio influence the population dynamics of *H. armigera* as reported by Wu and Li (1990), Lal (1996), Sahoo and Patnaik (2003[a]).

**Table 17. Biochemical profile of pods of different genotypes of pigeonpea**

| Sr. No | Genotype | Protein (%) | Sugars (%) | Phenols (mg/g) | Tannins (tannic acid equivalent/g dry matter | Flavonoids (mg/g) |
|---|---|---|---|---|---|---|
| 1 | ICPL-20139 | 15.07 (3.88) | 10.40 (3.23) | 48.52 | 11.47 | 4.04 |
| 2 | ICPL-20118 | 16.00 (4.00) | 10.83 (3.29) | 23.90 | 5.27 | 1.65 |
| 3 | ICPL-99004 | 15.87 (3.98) | 10.60 (3.26) | 32.22 | 8.30 | 3.01 |
| 4 | ICP-990016 | 14.03 (3.75) | 9.70 (3.11) | 54.06 | 12.97 | 5.18 |
| 5 | ENT-11 | 13.47 (3.67) | 6.93 (2.63) | 84.37 | 17.93 | 7.78 |
| 6 | ICP-10531 | 13.90 (3.73) | 9.30 (3.05) | 58.54 | 14.07 | 5.43 |
| 7 | ICP-13198 | 14.43 (3.80) | 8.83 (2.97) | 56.00 | 12.13 | 5.19 |
| 8 | ICPHRL-4978-5 | 15.45 (3.93) | 10.50 (3.24) | 31.44 | 8.10 | 2.55 |
| 9 | ICPHRL-4979-2 | 13.80 (3.71) | 9.47 (3.08) | 71.31 | 14.10 | 7.17 |
| 10 | ICPHRL-4985-1 | 17.63 (4.20) | 10.43 (3.23) | 28.45 | 8.13 | 2.58 |
| 11 | ICPHRL-4985-10 | 15.50 (3.94) | 10.30 (3.21) | 41.86 | 11.57 | 3.87 |
| 12 | ICPHRL-4989-7 | 16.47 (4.06) | 10.53 (3.24) | 39.01 | 7.80 | 3.57 |
| 13 | ICPL-20062 | 14.30 (3.78) | 10.00 (3.16) | 43.79 | 10.43 | 3.73 |
| 14 | ICPL-332 (R) | 13.70 (3.70) | 8.13 (3.16) | 67.55 | 17.83 | 5.93 |
| 15 | ICPL-909 | 13.73 (3.70) | 9.50 (2.85) | 58.04 | 12.10 | 4.64 |
| 16 | ICPL-97253 | 14.57 (3.81) | 9.70 (3.08) | 54.31 | 11.63 | 4.75 |
| 17 | PPE-45-2 | 14.27 (3.77) | 9.50 (3.11) | 54.24 | 13.53 | 4.56 |
| 18 | ICPL-87 (S) | 16.17 (4.02) | 10.67 (3.12) | 32.56 | 4.87 | 2.57 |
| 19 | ICPL-87119 | 14.73 (3.84) | 9.60 (3.08) | 50.10 | 10.70 | 3.99 |
| 20 | PKV-TARA | 15.07 (3.88) | 10.10 (3.27) | 51.06 | 9.87 | 3.81 |
| 21 | AKT-8811 | 14.80 (3.85) | 9.83 (3.10) | 50.29 | 9.83 | 4.39 |
| 22 | BSMR-736 | 15.30 (3.91) | 10.60 (3.18) | 32.03 | 5.27 | 2.97 |
| 23 | ICPH-2671 | 14.47(3.80) | 10.00 (3.14) | 43.46 | 8.43 | 4.10 |
| 24 | ICPH-2740 | 14.50 (3.81) | 9.77 (3.26) | 48.25 | 10.00 | 3.99 |
| | **S.Em. ±** | **0.03** | **0.04** | **3.05** | **0.41** | 0.04 |
| | **CD at 5%** | **0.07** | **0.11** | **8.18** | **1.11** | 0.10 |
| | **CV %** | **0.83** | **1.61** | **7.84** | **4.76** | 1.09 |

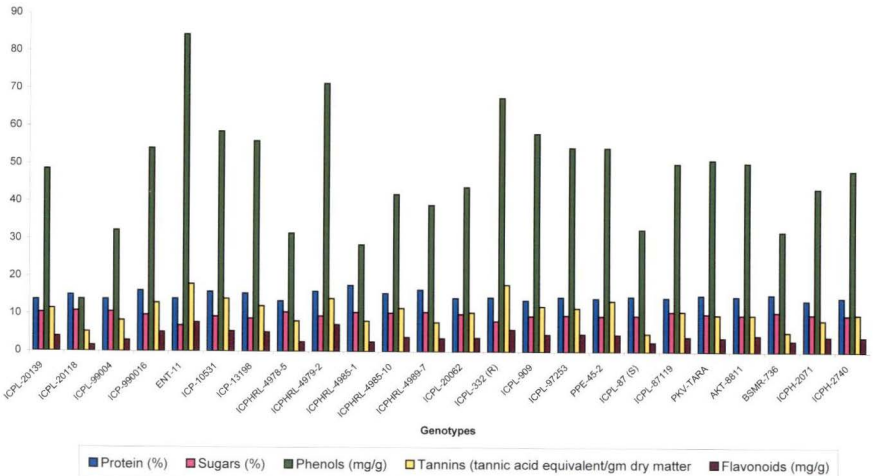



**Fig.18.Biochemical profile of pods of different genotypes of pigeonpea**

### 4.5.2 Total soluble sugars

Total sugar content of flowers and pods of pigeonpea genotypes differed significantly. Lowest quantity of total sugars was observed in genotype ENT-11 (6.93%) and was significantly superior over remaining all treatments. Former was followed by resistant check genotype ICPL-332 which had 8.13 per cent sugar and was also significantly superior over rest of the treatments. Genotype ICP-13198 had 8.83 per cent sugar and was followed by ICP-10531 (9.30%), PPE-45-2, ICPL-909 (9.50%) and ICPHRL-4979-2 (9.47%) and was at par with each other. Moderate per cent sugar content was noticed in genotype ICPL-87119 (9.60%) followed by ICPL-97253 and ICP-990016 (9.70%), ICPH-2740 (9.77%), AKT-8811 (9.83%), ICPH-2671 and ICPL-20062 (10%), and PKV-TARA (10.10%) in their order and was statistically at par with each other. Highest sugar content was observed in ICPL-20118 (10.83%) followed by ICPL-87 (10.67%), ICPL-99004 and BSMR-736 (10.60%), ICPHRL-4978-5 (10.50%), ICPHRL-4989-7 (10.53%), ICPL-20139(10.40%), ICPHRL-4985-1 (10.43%) and ICPHRL-4985-10, (10.30%) (Table-17, Fig.18).

Similar observations also made by Singh and Jotwani (1980) and Khurana and Verma (1983), that higher sugar content noticed in the susceptible genotypes.

Knap et al. (1996) observed that Early maturity varieties (UPAS-120, ICPL-87, and TA-10) were susceptible to pod borer damage had significantly higher total sugar content (3.56 to 4.70 per cent) than the late maturing cultivars (PT-35, PT-25, C-11, N-290-21) (2.99 to 3.30 per cent). Sharma et al. (2009) reported that expression of resistance to *H. armigera* in pigeonpea genotypes is associated with low amounts of sugar.

### 4.5.3 Total phenols

The data on quantity of phenols available in flowers and pods of pigeonpea genotypes (Table-17, Fig.18) revealed that higher phenols was found in genotype ENT-11( 84.37 mg/g) which was significantly superior than rest of the tested genotypes. It was followed by Genotype ICPHRL-4979-2 (71.31 mg/g) and resistant check ICPL-332 (67.55 mg/g) which were at par with each other and significantly superior to remaining treatments. Genotype ICP-10531 noticed 58.54 mg/g phenols which was

followed by ICPL-909 (58.04 mg/g), ICP-13198 (56 mg/g), ICPL-97253 (54.31 mg/g), PPE-45-2 (54.24 mg/g) and ICP-990016 (54.06 mg/g) in their order and were at par with each other. Moderate quantity of phenols was recorded in genotype AKT-8811 (50.29 mg/g) followed by ICPL-87119 (50.10mg/g), ICPL-20139 (48.52 mg/g), ICPH-2740 (48.25 mg/g) and ICPL-20062 (43.79 mg/g) in their order and were statistically at par with each other. Lowest quantity of phenols was observed in genotype ICPL-20118 (23.90 mg/g) which was significantly lower than remaining treatments. It was followed by ICPHRL-4985-1 (28.45 mg/g), ICPHRL-4978-5 (31.44 mg/g), BSMR-736 (32.06 mg/g), ICPL-99004 (32.22 mg/g) and susceptible check ICPL-87 (32.56 mg/g) in their order and was at par with each other.

Annadurai et al. (1990) suggested that the relative concentrations of various phenols play an important role in determining suitability of pigeonpea plant tissues. The compound resorcinol may be the cause of poor larval growth and survival on leaves. Guerra et al. (1990) observed that addition of phenolic compounds to the diet increased larval mortality and time required for the larvae to reach pupation and reduced rate of larval development. Pupal weight was reduced, but to a lesser extent than time to pupation.

Murkute et al. (1993) reported that the late maturing cultivars of pigeonpea were resistant to pod borer damage due to high content of polyphenols to the susceptible medium and early maturing varieties. Ganapathy (1996) observed that low amount of phenols in pigeonpea flowers are associated with susceptibility to spotted pod borer *M. testulais*. Similar observations have been reported by Sahoo and Patnaik (2003). Verulkar and Singh (2000) reported that vanillin acid showed a high correlation with pod borer resistance

Rizwana Banu et al (2007) identified three phenols (Benzoic acid, Paranitro phenol and Orcinol) in different generations of pigeonpea and reported that concentrations of phenols were higher in tolerant cultivars (ICP-13201) than susceptible (CO-5). Sharma et al. (2009) reported that expression of resistance to *H. armigera* in pigeonpea genotypes is associated with high amounts of condensed tannins and polyphenols.

Jagtap et al. (2012) reported that resistance to *H. armigera* was significantly negatively correlated with total phenol content. Thus, total phenol content plays an important role and imparting resistance in pigeonpea genotypes. Hence the present findings are in conformity with the previous findings.

**4.5.4 Tannins**

The levels of tannins revealed significant differences among the tested genotypes (Table-17 Fig.18). The highest level of tannins was observed in genotype ENT-11 (17.93) which was significantly higher than rest of the treatments. It was followed by genotype ICPL-332 (17.83) it was also significantly higher than rest of the treatments. Genotype ICPHRL-4979-2 recorded (14.10) level of tannins which was followed by ICP-10531 (14.07) and PPE-45-2 (13.53) in their order and was at par with each other. Moderate lavels of tannins was recorded in Genotype ICP-13198 (12.13) followed by ICPL-909 (12.10), ICPL-97253 (11.63), ICPHRL-4985-10 (11.57), ICPL-20139 (11.47) and ICPL-87119 (10.70) in their order and were at par with each other. Lowest quantity of tannins was recorded in susceptible genotype ICPL-87 (4.87) followed by BSMR-736 and ICPL-20118 (5.27). The remaining genotypes recorded more tannins contents than susceptible check ICPL-87 which ranged from 7.8 in ICPHRL-4989-7 to 10.43 in ICPL-20062.

Martin et al (1987) indicated that there is little evidence to suggest that condensed tannins inhibit digestion in insects, but the adverse effects of condensed tannins might be due to their role as feeding deterrents. Sharma et al. (1993) reported the antifeednt activity of tannins in sorghum against insects.

Sharma et al. (2009) reported that expression of resistance to *H. armigera* in pigeonpea genotypes is associated with high amounts of condensed tannins and polyphenols. Jagtap et al. (2012) reported that resistance to *H. armigera* was significantly negatively correlated with total tannin content. High levels of tannins in the pigeonpea genotypes protect themselves from the attack of the borer. The present findings thus in the tune to the previous results.

### 4.5.5 Flavonoids

The quantity of flavonoids in flowers and pods of twenty four genotypes ranged from 1.65 mg/g to 7.78 mg/g (Table-17, Fig.18). The highest quantity of flavonoids was observed in genotype ENT-11 (7.78 mg/g) and was significantly superior over remaining all genotypes. Genotype ICPHRL-4979-2 recorded (7.17 mg/g) flavonoids followed by resistance check ICPL-332 (5.93 mg/g) and ICP-10531 (5.43 mg/g) in their order and were significantly superior over each other and rest of the genotypes. Genotype ICP-13198 recorded 5.19 mg/g quantity of flavonoids followed by ICP-990016 (5.18 mg/g) and was at par with each other and was significantly superior over remaining treatments. Moderate quantity of flavonoids was recorded in ICPL-909 (4.75 mg/g), ICPL-97253 (4.56 mg/g), and AKT-8811 (4.39 mg/g). Lowest quantity of flavonoids was observed in genotype ICPL-20118 (1.65 mg/g) which was significantly lower than remaining genotypes followed by genotype ICPHRL-4989-5 (2.55 mg/g), susceptible check ICPL-87 (2.57 mg/g) and ICPHRL-4985-1 (2.58 mg/g) in their order and were statistically at par with each other.

Simmonds and Stevenson (2001) isolated four isoflavonoids from wild relatives of chickpea and reported their antifeedant activity against *H. armigera* larvae. The isoflavonoids were tested in combinations and with chlorogenic acid; the combinations containing judaicin and maackiain were most active, and chlorogenic acid enhanced the antifeedant activity of all four isoflavonoids. Kranthi et al. (2003) reported that semilooper *Anomis flava* Fab., feeding on in vivo plants induced an increased concentration of quercetin, which caused growth inhibition of larvae.

Mallikarjuna et al. (2004) demonstrated a combined effect of all the three flavonoids (quercetin, chlorogenic acid and rutin) in lines derived from wild Arachis spp. various developmental stages of larval, pupal and moth deformities, thus leading to significant mortalities. The results from this study indicate that the presence of three flavonoids may play an important role for resistance to *H. armigera* and *S. litura* not only in groundnut but also in pigeonpea.

Onyilagha et al. (2004) investigated thirty seven flavonoid compounds for their effect on feeding choice with *Mamestra configurata*. Unsubstituted flavones and flavanone were the strongest feeding deterrents in choice bioassay. In a no-choice bioassay, flavones reduced both larval weight as well as larval and pupal development time.

Jadhav et al. (2012) studied the effect of three flavonoids namely chlorogenic acid, querecetin and rutin at varying concentrations on growth, development and mortality of larvae of *H. armigera* in artificial diet. Rutin caused significant effect on the inhibition of *H. armigera* larvae in higher concentrations, larvae spent 30-51 days excess in III–V instar which had negative impact on growth because of cessation of feeding. Healthy *H. armigera* moth emergence was common in chlorogenic acid and quercetin, but the moths did not produce any progeny. Perusal of foregoing literature it can be inferred that flavonoids influences adversely on the growth and development of larvae. Thus, the present results are in the line of previous findings.

### 4.5.6 Correlation of Biochemicals with oviposition and per cent damage

**Table 18. Correlation of Biochemicals with oviposition and per cent damage**

| Biochemicals | Oviposition | % damage |
|---|---|---|
| Proteins | 0.417* | 0.533** |
| Sugars | 0.592** | 0.604** |
| Tannins | -0.464* | -0.753** |
| Flavonoids | -0.567** | -0.660** |
| Phenols | -0.511* | -0.607** |

* Significant at 5% ** Significant at 1% NS – Non-Significant

Protein content of flowers and pods showed slightly significant and positive correlation (Table-16) between the numbers of eggs laid (r=0.417) and highly positive significant and positive with per cent pod damage (r=0.533). Soluble sugars showed highly significant and positive correlation with numbers of eggs laid (r=0.592) and per cent pod damage (r=0.604). Tannins in flowers and pods had significant and negative

correlation between the numbers of eggs laid (r= -0.464) and highly significant and negative with per cent pod damage (r= -0.753). Flavonoids showed highly significant and negative correlation (r=-0.567) with numbers of eggs laid and per cent pod damage (r=-0.660). Concentration of phenols in flowers and pods was significantly and negatively correlated (r=-0.511) with oviposition and highly significant and negative correlated (r= -0.511) with per cent pod damage (r= -0.607)

**4.5.7 Correlation of Biochemicals with Larval Development**

Protein in flowers and pods showed (Table-19) significant and positive correlation with larval weight, larval period, average fecundity/ female and per cent hatchability of eggs and highly significant and positive correlation with growth index and male/female ratio. Correlation coefficient were non significant with larval mortality, pupal weight, pupal period, per cent pupation, adult emergence, male and female longevity.

Sugars content in flowers and pods showed a strong positive correlation with larval weight, pupal weight, per cent pupation, average fecundity/ female, per cent hatchability of eggs, and male and female longevity had significant and positive correlation with and adult emergence, but significant and negative correlation with pupal period.

**Table 19. Correlation of Biochemicals with Larval Development**

| Larval development | Proteins | Sugars | Tannins | Favonoids | Phenols |
|---|---|---|---|---|---|
| Larval Wt | 0.434* | 0.604** | -0.598** | -0.737** | -0.630** |
| Larval Period | 0.412* | -0.613** | 0.638** | 0.647** | 0.579** |
| Larval Mortality | -0.058 | -0.743** | 0.670** | 0.682** | 0.640** |
| Pupal Wt | -0.024 | 0.568** | -0.767** | -0.752** | -0.578** |
| Pupal Period | 0.022 | -0.450* | 0.587** | 0.691** | 0.564** |
| Pupation % | 0.132 | 0.570** | -0.742** | -0.747** | -0.710** |
| Adult Emergence | -0.001 | 0.505* | -0.626** | -0.695** | -0.785** |
| Growth Index | 0.533** | 0.594** | -0.517** | -0.540** | -0.656** |
| Female/ Male ratio | 0.528** | 0.330 | -0.321 | -0.345 | -0.215 |
| Av. Fecundity/ Female | 0.489* | 0.602** | -0.605** | -0.690** | -0.553** |
| Hatchability% | 0.436* | 0.603** | -0.589** | -0.643** | -0.592** |
| Longevity Male | 0.029 | 0.611** | -0.598** | -0.535** | -0.667** |
| Longevity Female | 0.092 | 0.683** | -0.559** | -0.675** | -0.677** |

* Significant at 5% ** Significant at 1% NS – Non-Significant

Tannins content in flowers and pods showed a strong negative correlation with larval weight, pupal weight, pupal period, per cent pupation, adult emergence, average fecundity/ female, per cent hatchability of eggs, and male and female longevity and highly significant and positive correlation with larval period and larval mortality (except female/ male ratio).

Concentration of flavonoids in flowers and pods showed a strong negative correlation with larval weight, pupal weight, pupal period per cent pupation, adult emergence, average fecundity/ female, per cent hatchability of eggs, and male and female longevity and highly significant and positive correlation with larval period and larval mortality (except female/ male ratio).

Total phenols in flowers and pods showed a strong negative correlation with larval weight, pupal weight, pupal period per cent pupation, adult emergence, average fecundity/ female, per cent hatchability of eggs, and male and female longevity and highly significant and positive correlation with larval period and larval mortality (except female/ male ratio).

Most of the previous workers have expressed the similar views those are Fitt (1989), Wu and Li (1990), Lal (1996) Sahoo and Patnaik (2003[a]). Pertaining to crude protein, Singh and Jotwani (1980) and Khurana and Verma (1983) and Sharma et al., (2009) for total sugars, Sharma et al., (2009) and Jagtap et al., (2012) reported that resistance to *H. armigera* was significantly and negatively correlated with total phenol and tannin contents. Jadhav et al., (2012) recorded adverse effect of flavonoids on growth and development of *H. armigera* larva. Thus the present findings are in tune to the views expressed by the previous workers.

### 4.6 Relative feeding preference by the third instar larvae of *H. armigera* towards the flowers of 24 genotypes.

#### 4.6.1 Feeding preference towards the flowers under no choice conditions

The data (Table-20, Fig.19) revealed that there were significant differences in feeding preference by the third instar larvae towards the flowers of different pigeonpea genotypes.

**Table 20. Relative feeding preference by the third instar larva of *H. armigera* towords the flowers of different genotypes of pigeonpea under no choice conditions**

| Sr. No | Genotype | Damage Rating (24 h) |
|---|---|---|
| 1 | ICPL-20139 | 4.88 |
| 2 | ICPL-20118 | 6.18 |
| 3 | ICPL-99004 | 6.42 |
| 4 | ICP-990016 | 5.08 |
| 5 | ENT-11 | 3.83 |
| 6 | ICP-10531 | 4.63 |
| 7 | ICP-13198 | 4.63 |
| 8 | ICPHRL-4978-5 | 5.37 |
| 9 | ICPHRL-4979-2 | 4.42 |
| 10 | ICPHRL-4985-1 | 5.50 |
| 11 | ICPHRL-4985-10 | 5.20 |
| 12 | ICPHRL-4989-7 | 5.82 |
| 13 | ICPL-20062 | 5.40 |
| 14 | ICPL-332 (R) | 4.45 |
| 15 | ICPL-909 | 4.63 |
| 16 | ICPL-97253 | 4.78 |
| 17 | PPE-45-2 | 4.57 |
| 18 | ICPL-87 (S) | 6.73 |
| 19 | ICPL-87119 | 4.85 |
| 20 | PKV-TARA | 5.23 |
| 21 | AKT-8811 | 5.22 |
| 22 | BSMR-736 | 6.98 |
| 23 | ICPH-2671 | 5.05 |
| 24 | ICPH-2740 | 5.07 |
| **S.Em. ±** | | **0.21** |
| **CD at 5%** | | **0.56** |
| **CV %** | | **4.89** |

R-Resistant check, S-Susceptible check.

Highest feeding was recorded in flowers of BSMR-736 (DR=6.98) followed by Susceptible check ICPL-87 (6.73) and ICPL-99004 (6.42) in their order and was at par with each other. Genotype ICPL-20118 record feeding preference of 6.18 followed by ICPHRL-4989-7 (5.82), ICPHRL-4985-1 (5.50), ICPL-20062 (5.40) and ICPHRL-4978-5 (5.37) in their order. Moderate feeding preference was observed in PKV-TARA (5.23), AKT-8811 (5.22), ICPHRL-4985-10 (5.20), ICP-990016 (5.08), ICPH-2740 (5.07) and ICPH-2671 (5.05). Significantly low feeding preference was observed in ENT-11 (3.83). It was followed by ICPHRL-4979-2 (4.42), ICPL-332 (4.45), PPE-45-5 (4.57), ICPL-909 ICP-13198, and ICP-10531 (4.63), ICPL-97253 (4.78), ICPL-87119 (4.85) and ICPL-20139 (4.88) in their order and at par with each other.

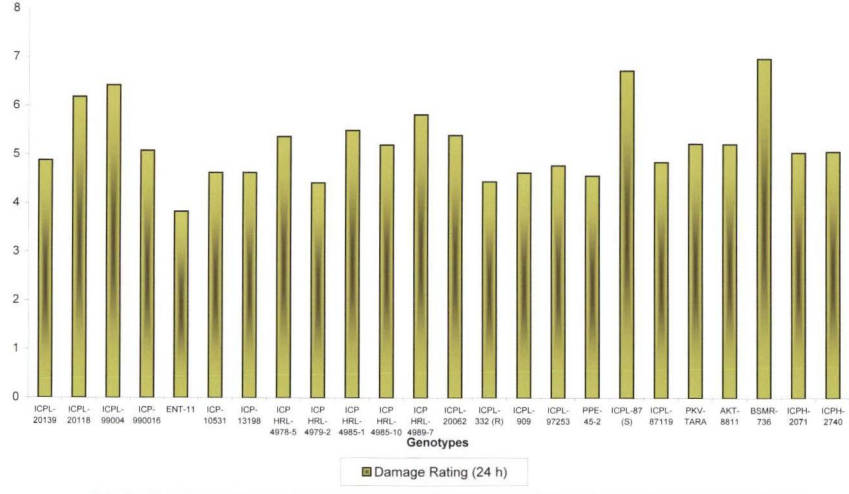



**Fig.19. Relative feeding preference by the third instar larva of H. armigera towards the flowers of different genotypes of pigeonpea under no choice conditions**

### 4.6.2 Feeding preference towards the flowers under dual choice conditions

Data presented in Table-21 and depicted in Fig. 20 revealed that, when the larvae were allowed to choose between flowers of the susceptible genotype ICPI-87 and flowers of test genotypes, all the genotypes tested positive't' values indicating more preference for the flowers of ICPL-87 as compared to test genotypes. This indicates that the larvae are able to select the nutritionally more optimum food when a choice is offered between resistant and susceptible genotypes.

**Table 21. Relative feeding preference by the third instar larva of *H. armigera* towards the flowers of different genotypes of pigeonpea under dual choice conditions**

| Sr. No | Genotype | Damage Rating (24 h) | | t-value |
|---|---|---|---|---|
| | | Test genotype | Control (ICPL-87) (S) | |
| 1 | ICPL-20139 | 4.77 | 6.32 | 3.10 |
| 2 | ICPL-20118 | 5.25 | 6.50 | 2.16 |
| 3 | ICPL-99004 | 4.52 | 6.33 | 2.56 |
| 4 | ICP-990016 | 4.28 | 6.30 | 3.60 |
| 5 | ENT-11 | 3.47 | 6.87 | 4.66 |
| 6 | ICP-10531 | 4.47 | 6.28 | 2.17 |
| 7 | ICP-13198 | 3.80 | 6.98 | 3.32 |
| 8 | ICPHRL-4978-5 | 4.65 | 6.33 | 2.72 |
| 9 | ICPHRL-4979-2 | 3.73 | 6.00 | 3.86 |
| 10 | ICPHRL-4985-1 | 4.80 | 6.25 | 2.96 |
| 11 | ICPHRL-4985-10 | 4.37 | 6.33 | 2.87 |
| 12 | ICPHRL-4989-7 | 4.45 | 6.50 | 3.12 |
| 13 | ICPL-20062 | 4.85 | 5.27 | 1.98 |
| 14 | ICPL-332 (R) | 3.60 | 6.68 | 3.78 |
| 15 | ICPL-909 | 3.78 | 5.67 | 2.94 |
| 16 | ICPL-97253 | 4.03 | 5.48 | 2.19 |
| 17 | PPE-45-2 | 3.92 | 6.80 | 3.74 |
| 18 | ICPL-87119 | 4.87 | 5.68 | 2.86 |
| 19 | PKV-TARA | 5.42 | 5.60 | 1.58 |
| 20 | AKT-8811 | 5.05 | 5.57 | 1.76 |
| 21 | BSMR-736 | 5.58 | 6.08 | 1.63 |
| 22 | ICPH-2671 | 4.67 | 5.75 | 1.79 |
| 23 | ICPH-2740 | 4.93 | 5.58 | 2.21 |

R-Resistant check, S-Susceptible check. t- test, significant

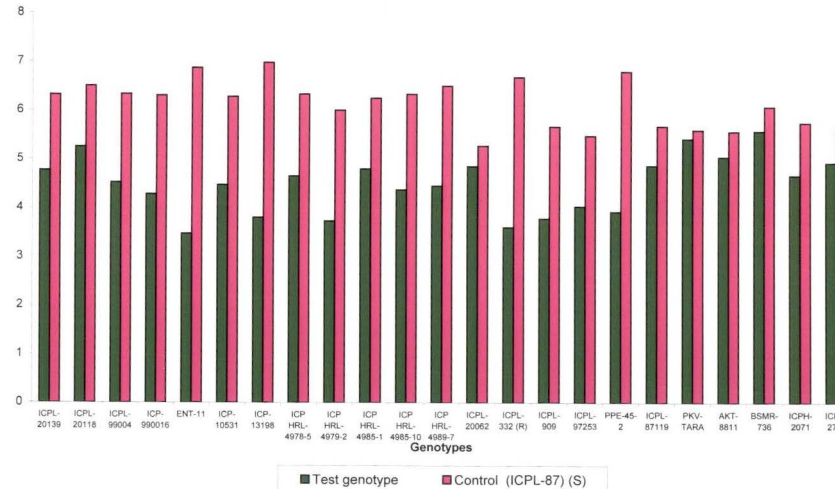



**Fig.20. Relative feeding preference by the third instar larva of *H. armigera* towards the flowers of different genotypes of pigeonpea under dual conditions**

### 4.6.3 Feeding preference towards the flowers under multi choice conditions

In case of multi choice conditions (Table-22, Fig.21) greater feeding was observed in BSMR-736 (DR= 6.73) followed by susceptible check ICPL-87 (6.67), ICPL-99004 (6.27), ICPHRL-4985-1 (6.20) and ICPL-20118 (6.07) in their order and was at par with each other. Moderate feeding was observed in AKT-881 and ICPH-2740 (5.43) followed by ICPH-2671 (5.30), ICPHRL-49878-5 (5.23), ICPL-20139 (5.20), ICPHRL-4989-7 and ICPL-87119 (5.13), ICPL-97253 (5.1), ICP-13198 (5.03), ICP-990016 (5), ICPHRL-4985-10 and PKV-TARA (4.97) in their order and were at par with each other. Least feeding was recorded in ENT-11 (3.73) followed by ICPHRL-4979-2 (4.10), ICPL-909 and ICPL-332 (4.33), and ICP-10531 (4.4) in their order and were at par with each other.

**Table 22. Relative feeding preference by the third instar larva of *H. armigera* towords the flowers of different genotypes of pigeonpea under multi choice conditions**

| Sr. No | Genotype | Damage Rating (24 h) |
|---|---|---|
| 1 | ICPL-20139 | 5.20 |
| 2 | ICPL-20118 | 6.07 |
| 3 | ICPL-99004 | 6.27 |
| 4 | ICP-990016 | 5.00 |
| 5 | ENT-11 | 3.73 |
| 6 | ICP-10531 | 4.40 |
| 7 | ICP-13198 | 5.03 |
| 8 | ICPHRL-4978-5 | 5.23 |
| 9 | ICPHRL-4979-2 | 4.10 |
| 10 | ICPHRL-4985-1 | 6.20 |
| 11 | ICPHRL-4985-10 | 4.97 |
| 12 | ICPHRL-4989-7 | 5.13 |
| 13 | ICPL-20062 | 4.63 |
| 14 | ICPL-332 (R) | 4.33 |
| 15 | ICPL-909 | 4.33 |
| 16 | ICPL-97253 | 5.10 |
| 17 | PPE-45-2 | 4.43 |
| 18 | ICPL-87 (S) | 6.67 |
| 19 | ICPL-87119 | 5.13 |
| 20 | PKV-TARA | 4.97 |
| 21 | AKT-8811 | 5.43 |
| 22 | BSMR-736 | 6.73 |
| 23 | ICPH-2671 | 5.30 |
| 24 | ICPH-2740 | 5.43 |
| | S.Em. ± | 0.25 |
| | CD at 5% | 0.67 |
| | CV % | 5.89 |

R-Resistant check, S-Susceptible check.

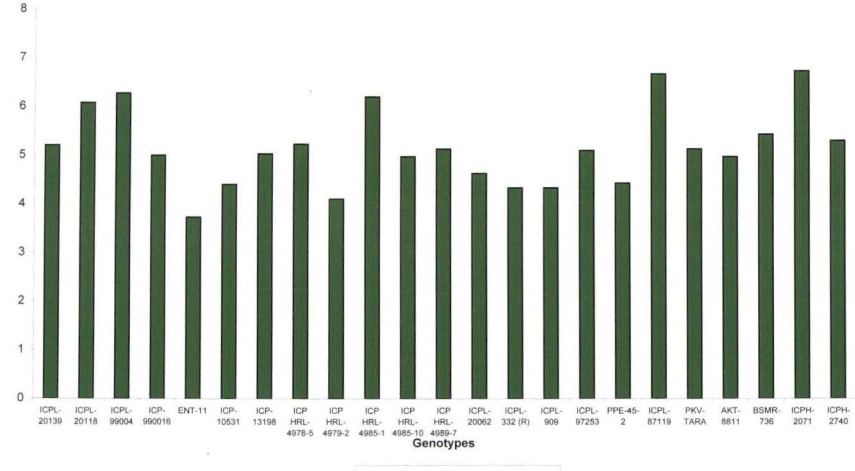



**Fig.21. Relative feeding preference by the third instar larva of *H. armigera* towards the flowers of different genotypes of pigeonpea under multi choice conditions**

The third instar larvae feed more on flowers compared to the leaf material. This observation was common for all the genotypes. The third instar larvae spent more time on flowers and pods than on leaves. Among all the genotype tested, there was high damage in flowers and pods of the susceptible genotypes such as BSMR-736, ICPL-87 and ICPL-99004. These observations were similar to genotypic reaction under field conditions. In case of ENT-11, ICPHRL-4979-2, ICPL-332, PPE-45-5, ICPL-909, ICP-13198, ICP-10531, ICPL-97253, ICPL-87119 and ICPL-20139, lower flower damage rating was observed under field and laboratory conditions.

**4.7 Relative feeding preference by the third instar *H. armigera* larvae towards the pods of 24 genotypes.**

**4.7.1 Multi choice conditions**

The data revealed that (Table-23, Fig.22) lowest damage rating after 48 hrs was observed in pods of ENT-11 genotype (DR=1.55), followed by resistance check ICPL-332 (1.97) which was at par with each other. Next group of genotype which recorded low damage rating was ICP-13198 (2.53) followed by ICPHRL-4979-2 (2.57), ICPL-909 (2.73) and ICP-990016 (2.8) in their order. Moderate damage rating was observed in genotypes ICP-10513 (3.17) followed by ICPL-97253 (3.23), PPE-45-2 (3.3), PKV-TARA (3.33) and ICPHRL-4985-10 (3.5) in their order and was at with each other. Highest pod damage rating was observed in susceptible check ICPL-87 (DR=6.07). It was followed by ICPL-99004 and BSMR-736 (5.83), and ICPL-20118 (5.57) in their order. Similar trend was noticed after 24 hrs damage rating also.

Among all the genotype tested, there was high damage in pods of the susceptible genotypes such as BSMR-736, ICPL-87 ICPL-99004 and ICPL-20118. These observations were similar to genotypic reaction under field conditions. In case of ENT-11, ICPHRL-4979-2, ICPL-332, PPE-45-5, ICPL-909, ICP-13198, ICP-10531, ICPL-97253, ICPL-87119 and ICPL-20139, lower pod damage was observed under field and laboratory conditions. The results of these studies suggested that the compounds on pod surface of pigeonpea genotypes play an important role in acceptance or rejection of food by *H. armigera* larvae.

**Table 23. Relative feeding preference by the third instar larva of *H. armigera* towards the pods of different genotypes of pigeonpea under multi choice conditions**

| Sr. No | Genotype | Damage Rating | |
|---|---|---|---|
| | | 24 (hrs) | 48 (hrs) |
| 1 | ICPL-20139 | 1.67 | 3.83 |
| 2 | ICPL-20118 | 1.70 | 5.57 |
| 3 | ICPL-99004 | 1.67 | 5.83 |
| 4 | ICP-990016 | 1.65 | 2.80 |
| 5 | ENT-11 | 0.75 | 1.55 |
| 6 | ICP-10531 | 1.08 | 3.17 |
| 7 | ICP-13198 | 1.03 | 2.53 |
| 8 | ICPHRL-4978-5 | 1.67 | 5.33 |
| 9 | ICPHRL-4979-2 | 0.78 | 2.57 |
| 10 | ICPHRL-4985-1 | 1.37 | 5.00 |
| 11 | ICPHRL-4985-10 | 1.30 | 3.50 |
| 12 | ICPHRL-4989-7 | 1.60 | 5.57 |
| 13 | ICPL-20062 | 1.40 | 4.47 |
| 14 | ICPL-332 (R) | 0.53 | 1.97 |
| 15 | ICPL-909 | 1.57 | 2.73 |
| 16 | ICPL-97253 | 1.25 | 3.23 |
| 17 | PPE-45-2 | 1.10 | 3.30 |
| 18 | ICPL-87 (S) | 1.63 | 6.07 |
| 19 | ICPL-87119 | 1.32 | 4.80 |
| 20 | PKV-TARA | 1.70 | 3.33 |
| 21 | AKT-8811 | 1.70 | 4.10 |
| 22 | BSMR-736 | 2.03 | 5.83 |
| 23 | ICPH-2671 | 1.67 | 4.93 |
| 24 | ICPH-2740 | 1.53 | 4.47 |
| **S.Em. ±** | | **0.06** | **0.18** |
| **CD at 5%** | | **0.17** | **0.47** |
| **CV %** | | **5.65** | **5.35** |

R-Resistant check, S-Susceptible check.

Similar observations have been made by Sujana et al. (2012), they studied the feeding behaviour of pod borer *H. armigera*. Higher damage rating was in susceptible genotype ICPL-87 and lower damage

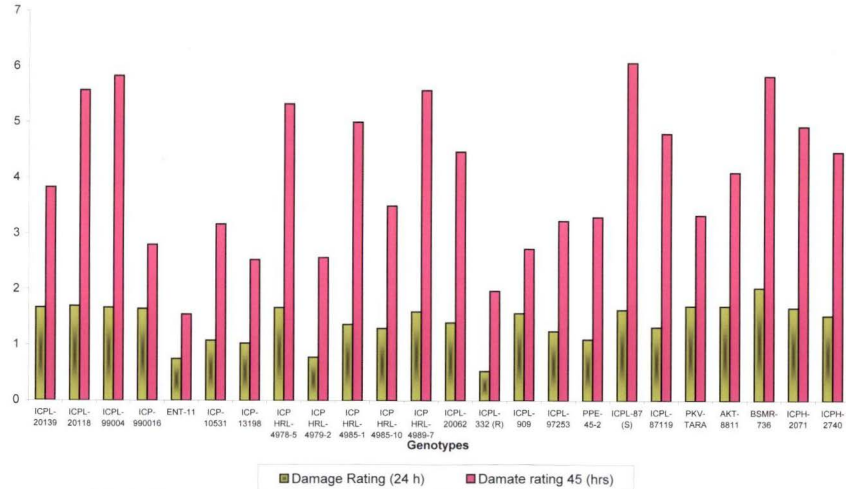



**Fig.22. Relative feeding preference by the third instar larva of *H. armigera* towards the flowers of different genotypes of pigeonpea under dual choice conditions**

rating in resistant ICPL-332 which might be due to phagostimulants and antifeedants, respectively on the pigeonpea pod surface. Thus, the susceptible genotypes favoured for feeding on the contrary resistant genotypes did not favour for feeding by *H. armigera*.

## CHAPTER V

# SUMMARY AND CONCLUSIONS

*Cajanus cajan* (Linn.) Millsp. commonly called pigeonpea, is an important pulse crop of Indian continent. Of the several biotic and abiotic constraints limiting pigeonpea production, insect pests cause a substantial loss in grain yield. Among those the pod borer, *Helicoverpa armigera* (Huber) (Lepidoptera:Noctuidae), is the most devastating pest. *Helicoverpa armigera* has a wide host range and hence, it has become difficult to control (Fitt, 1989; Mathhews, 1989). To overcome these losses farmers resort to excessive use of pesticides. Due to the continuous and excessive use of insecticides, the pest has developed considerable levels of resistance to most of the conventional insecticides, including the synthetic pyrethroids (Kranthi el al., 2002). Natural enemy activity on *H. armigera* in pigeonpea is quite low as compared to that on other crops such as sorghum (Bhatnagar et al, 1983). As a result, there is greater survival of this pest on pigeonpea causing a heavy loss in grain yield. In such situation, there is an urgent social call to develop safer alternative, method such as host plant resistance to suppress or minimize the pest population as a tool of IPM.

Host plant resistance against insect pests and pathogens is an economically viable and ecologically preferred alternative to other pest management strategies, particularly the synthetic pesticides. It is one of the cheapest and most effective management tools for reducing the damage by *H. armigera* as it does not require additional input, and does not affect the expression of other important agronomic traits. Therefore, host plant resistance can play a central role in integrated management of *H. armigera*.

Present investigations were therefore, planned with under following propositions.

- Screening of pigeonpea genotypes against *Helicoverpa armigera* (Hubner).
- To study antixenosis, antibiosis mechanisms of host plant resistance in selected genotypes against *Helicoverpa armigera* (Hubner) .
- To find out the morphological and biochemical bases of host plant resistance in selected genotypes.

The present investigation on "Host Plant Resistance Studies in pigeonpea genotypes against *Helicoverpa armigera* (Hubner)" was conducted at Department of Agril. Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, (Located at latitude $20.42^0$N, Longitude, 77.020E and at 307.415 M.S.L with normal rainfall of 818.6 mm) during *kharif* season of 2011-2012 and 2012-13, whereas, mechanism of resistance studies (antixenosis and antibiosis) and biochemical analysis were conducted under laboratory condition.

The observations in respect of *Helicoverpa armigera* (Hubner) on various genotypes of pigeonpea with their yield have been recorded during the course of screening of genotypes. The results are summarized as follows:

### 6.1 Field screening of pigeonpea genotypes against *Helicoverpa armigera* (Hubner) under field conditions.

Screening of twenty four genotypes of pigeonpea under field conditions was carried out in the field of Department of Agril. Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, with the view to evaluate comparative resistance in pigeonpea genotypes against *Helicoverpa armigera*. These trails were laid out in Randomise Block Design (RBD) replicated thrice.Each genotype had four rows with the spacing of 60 x 15 cm. There were 48 plants per genotype. Row from either side was kept as a border plants and remaining 24 from each genotype were used for recording observations (Ujagir et. al., 2005).

#### 6.1.1 Days to 50 per cent flowering and maturity

Among the genotypes evaluated, the days to 50 per cent flowering were in the range of 82 to 121 days. The days to 50 per cent

flowering was lowest in susceptible check ICPL-87 (82 day) and highest in ENT-11 (121 days). Early maturity was recorded in susceptible check ICPL-87 (119 days) and delayed maturity was recorded in ENT-11 (183 days).

**6.1.2 Eggs and larval abundance**

Relative preferrence for oviposition on genotype under evaluation was evaluated under field condition. During 2011 *kharif* season lowest numbers of eggs and larvae per plant were recorded on genotype ENT-11 with 5 and 1.8, respectively. Highest numbers of eggs and larvae were recorded on susceptible check ICPL-87 with 15.8 and 8.7, respectively. During 2012 *kharif* season lowest numbers of eggs and larvae were recorded on ENT-11 (6.5) and (2.3), respectively. Whereas, highest numbers of eggs and larvae were recorded on susceptible check ICPL-87 with 18.2 eggs and 9.7 larvae respectively.

**6.1.3 Pod damage rating under field condition**

Visual pod damage rating indicated the relative tolerance of pigeonpea genotype against *H. armigera*. Mean pod damage rating levels of 2011 and 2012 seasons revealed that, all the tested genotypes exhibited nearly similar reaction during both the seasons. The pooled mean of pod damage rating of both the trials ranged between 1.95 to 5.98. Lowest damage rating was recorded in genotype ENT-11 (1.95), while highest damage rating was recorded in genotype ICPL-87 (5.98).

**6.1.4 Per cent pod damage**

Lower per cent pod damage by *H. armigera* at harvest may be attributed to the less preference for oviposition and antibiosis effect of the genotype under evaluation. Per cent pod damage by *H. armigera* at the time of harvest revealed significant differences. Lowest pod damage was recorded in ENT-11 (5.97%) followed by resistant check ICPL-332 (9.75%), ICPHRL-4979-2 (13.08%), ICPL-97253 (13.90%), ICPL-909 (13.92%) and PPE-45-2 (14.08%). Highest per cent of pod damage was recorded in susceptible check ICPL-87 (24.33%) and was followed by BSMR-736 (22.17%).

### 6.1.5 100 Seed weight

Among the genotype tested highest 100 seed weight was recorded in ENT-11 (14.95 g) followed by ICPH-2740 (13.01 g), ICPHRL-4978-5 (12.35 g) and BSMR-736 (12.31 g). Lowest 100 seed weight was recorded in genotype ICP-13198 (8.99 g) followed by ICPL-99004 (9.51 g), PPE-45-2 (9.57 g) and ICPI-20062 (9.89 g).

### 6.1.6 Grain yield per hectare

Superior agronomic traits including yield parameters associated with desired trait of resistance against *H. armigera* is preferred for selection of genotypes under evaluation. Highest grain yields were recorded in PKV-TARA (17.69q/ha) followed by ICPL-97253 (16.92q/ha), ICPL-87119 (16.72q/ha), PPE-45-2 (16.62q/ha), ICP-13198 (16.10q/ha), AKT-8811 (16.10q/ha), ICPL-909 (16.02q/ha) and resistant check ICPL-332 (15.56q/ha). Lowest grain yield was recorded in ENT-11 (6.84q/ha) followed by susceptible check ICPL- 87 (7.66q/ha).

## 6.2 Mechanism of host plant resistance in pigeonpea to *H. armigera*

Under laboratory conditions, 24 genotypes of pigeonpea were evaluated for their resistance to *H. armigera* by studying the antixenosis mechanism of resistance. Antixenosis (non-preference) for oviposition was studied under no-choice, dual- choice and multi-choice conditions. It was an important component of resistance to *H. armigera* in the different genotypes of pigeonpea where the numbers of eggs laid within 72 hrs (3 days) were recorded. The studies on oviposition preference, conducted under no-choice, dual-choice and multi-choice conditions revealed that the susceptible check ICPL-87 was most preferred followed by ICPL-20118, BSMR-736, ICPHRL-4985-1,and ICPHRL-4978-5.

### 6.2.1 Non-preference/ antixenosis for oviposition to *H. armigera* (No choice test)

Data regarding oviposition preference revealed that each female moth laid 67 to 214 eggs on different test genotypes. Even under no choice condition the genotype ENT-11 had least egg laying of 67 eggs per female which was significantly lowest than rest of the genotypes. It was followed by ICPI-332, ICPHRL-4979-2, (108 eggs), ICPL-909 (117 eggs),

and ICPL-97253 (118 eggs). Highest egg laying was observed on susceptible check ICPL-87 (214 eggs), which was highly preferred for oviposition by *H. armigera*.

### 6.2.2 Non-preference/ antixenosis for oviposition to *H. armigera* (Dual choice test)

Ovipositional preference of *H. armigera* gravid females under presence of choice (susceptible check ICPI-87) revealed relatively higher non preference by laying lower numbers of eggs on ENT-11 (27.26 eggs) followed by ICP-10531 (32.42 eggs), ICPL-87119 (38.72 eggs), ICP-13198 (39.27 eggs), ICPH-2671 (39.48 eggs), and ICPL-97253 (46.72 eggs) as compared to the susceptible genotype ICPL-87. The relative oviposition preference for all the test genotypes was lower than ICPL-87 susceptible check.

### 6.2.3 Non-preference/ antixenosis for oviposition to *H. armigera* (Multi choice test)

Ovipositional preference of *H. armigera* under multi-choice conditions was significantly lower on ENT-11 (56 eggs) followed by ICPL-332 (78 eggs), ICPHRL-4979-2, ICPL-909 (104 eggs), ICP-10531 (107 eggs), ICP-13198 (111 eggs), ICPHRL- 4985-10 (114 eggs), PPE-45-2, ICPL-97253, ICPL-87119 and ICPH-2740 (117 eggs) when compared with susceptible check ICPL-87 (181 eggs). It was the reaction of relative preference of *H. armigera* female for oviposition under field condition. Similar trend was also evident during present study.

## 6.3 Antibiosis

### 6.3.1 Growth of *H. armigera* reared on flowers and pods of different genotypes of pigeonpea.

The antibiosis mechanism of resistance to *H. armigera* was measured in terms of mortality, reduced body weights, prolongation of larval period, pupal weight, per cent pupation, per cent of adult emergence, growth index, female/male ratio, average fecundity/ female, per cent hatchability of eggs, and adult longevity by rearing larvae on the flowers and pods of various pigeonpea genotypes. It was found in increasing trend when the larvae reared on the flowers and pods of resistant genotypes of

pigeonpea (ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253). The larval and pupal weights on the resistant genotypes were significantly lower than those on the susceptible pigeonpea genotypes (ICPL-87, ICPL-20118, BSMR-736, ICPL-99004 and ICPHRL-4985-1). At the same time higher larval mortality was observed on the resistant genotypes of pigeonpea compared to the susceptible pigeonpea genotypes. Lower pupation and adult emergence was recorded in the larvae reared on the resistant pigeonpea genotypes compared to the susceptible pigeonpea genotypes. Lower larval weights and longer developmental periods were observed in the larvae reared on flowers and pods of resistant genotypes of pigeonpea. The mean developmental time for *H. armigera* larvae grown on the resistant genotypes of pigeonpea was relatively longer compared to the larvae reared on the susceptible genotypes of pigeonpea. Antibiosis effect of resistant pigeonpea genotypes on *H. armigera* was evident in terms of lower larval and pupal weight. The effect was also visible in terms of higher larval duration and lower weight gained by the larvae, reflecting in higher larval mortality. These results indicate that the growth inhibitor or antifeedent substance or both existed in the resistant genotypes.

### 6.4 Bases of Host Plant Resistance

#### 6.4.1 Bio-physical basis of resistance

**Trichome types and their density in 24 genotypes**

The most common resistance mechanism conferred by the morphological structures is the presence of trichomes. To record the morphological differences in trichomes and their density, the calyx and pods of different genotypes of pigeonpea were examined under compound microscope. Four types of trichomes; type A, type B, type C and type D, were identified on the calyxes and pods of the 24 pigeonpea genotypes. Of the four trichomes, type A and type B were glandular, and type C and type D were non-glandular in nature. The variation in their structure and density are responsible for the variation in the levels of resistance in these genotypes. Review of literature suggest that the secretions of glandular trichomes, type A and type B, on the flowers and pods of genotype act as an attractant to the insect and thus contributing for genotype susceptiblity (

ICPL-87, ICPL-20118, BSMR-736, ICPL-99004 and ICPHRL-4985-1), whereas, the high density of non-glandular tnchomes, type C and type D, on the pods act as deterrent to the insect resulting in non-preference of female moths for oviposition on the resistsant genotypes (ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253). A significant and positive correlation was observed between the numbers of eggs laid, per cent pod damage and the density of glandular (type A) trichomes on calyxes and pods of tested genotypes. Number of eggs laid, per cent pod damage were significantly and negatively correlated with the density of non-glandular (type C) and (type D) trichomes. While Type B, trichomes showed no association with egg laying, larval abundance, and pod damage.

**6.4.2 Biochemical basis of resistance:**

Biochemical profile of genotype decides the level of tolerance to pest. Biochemical composition of flowers and pods of 24 genotypes of pigeonpea was studied by estimating the amounts of crude protein, total soluble sugars, phenols, tannins and also the flavonoids profiles. The amounts of crude protein and total soluble sugars were high in the susceptible genotypes of pigeonpea (ICPL-78, ICPL-20118, BSMR-736, ICPL-99004 and ICPHRL-4985-1) contributing to the susceptibility of genotypes.

Higher amount of phenols was recorded in the resistant genotypes of pigeonpea (ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253) compared to the susceptible genotypes of pigeonpea. The amount of tannin was higher in resistant genotypes as compared to the susceptible genotypes of pigeonpea. The percentage of flavonoids was higher in the flowers and pods of resistant genotypes compared to of susceptible genotypes of pigeonpea. The present studies indicated that high levels of resistance to *H. armigera* in resistant genotypes of pigeonpea may be attributed to lower amounts of sugars and proteins and high content of tannins, phenols, and flavonoids. However, further studies are necessary to understand the type of sugars, tannins, phenols, and proteins conferring resistance to *H. armigera*.

### 6.4.3 Correlation of biochemicals with oviposition and per cent pod damage

Protein and sugar content of flowers and pods showed significantly positive correlation with the numbers of eggs laid and per cent pod damage. Tannins, flavonoids and phenols in flowers and pods showed significantly negative correlation with the numbers of eggs laid and per cent pod damage under field conditions.

### 6.4.4 Correlation of biochemicals with larval development

Crude protein in flowers and pods showed significant and positive correlation with larval weight, larval period, average fecundity/ female and per cent hatchability of eggs. Highly significant and positive correlation with growth index and male/female ratio was evident, Whereas, correlation coefficient were non significant with larval mortality, pupal weight, pupal period, per cent pupation, adult emergence, male and female longevity. Total sugars content in flowers and pods showed a strong positive correlation with larval weight, pupal weight, per cent pupation, average fecundity/ female, per cent hatchability of eggs, and male and female longevity. Significantly positive correlation of sugar content with adult emergence was observed. Whereas, significant but negative correlation with pupal period was observed. These trends clearly signifying the role of sugars and proteins in confirming the susceptibility to the genotypes.

Tannins, flavonoids and phenols content in flowers and pods showed a strong negative correlation with the larval weight, pupal weight, pupal period per cent pupation, adult emergence, average fecundity/ female, per cent hatchability of eggs, and male and female longevity and highly significant and positive correlation with larval period and larval mortality (except female/ male ratio) was recorded indicating strong interference of these biochemical components in resistance to *H. armigera*.

## 6.5 Feeding preference of the third instar of *H. armigera* larvae towards the flowers and pods of 24 genotypes.

Relative feeding preference by the third-instar larvae of *H. armigera* towards the flowers and pods of 24 genotypes of pigeonpea was

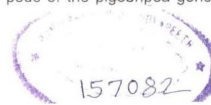
studied under no choice and multi-choice conditions. The differences in larval feeding preference were not apparent among the resistant pigeonpea genotypes under no-choice and multi-choice conditions. The biochemical cues may be responsible for their acceptance or rejection as food by the *H. armigera* larvae. In case of pods the larvae of *H armigera* showed less feeding preference towards the (ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198 and ICPL-97253) pigeonpea genotypes, where the percentage damage was low compared to that on the pods of susceptible pigeonpea genotype, ICPL 87.

An overview of the results pertaining to screening of pigeonpea genotypes against *H. armigera* revealed that antixenosis and antibiosis mechanisms of resistance are playing a key role in conferring resistance against *H. armigera*. The morphological (trichomes particularly type C and type D) and biochemical (Phenol, tannin, and flavonoids.) constituents in the pigeonpea genotypes were found to be contributing resistance against *H. armigera*.

These genotypes would be helpful in breeding programme for high and stable resistance to *H. armigera* in pigeonpea improvement programme. The resistance mechanisms involved in these genotypes can be exploited to develop varieties resistant/tolerant to *H. armigera*

## CONCLUSIONS

1. Based on the damage rating and per cent pod damage, the pigeonpea genotypes ENT-11, ICPL-332, ICPHRL-4979-2, ICP-10531, ICPL-909, PPE-45-2, ICP-13198, ICPL-97253 emerged out as promising and resistant to *H. armigera*. These genotypes were therefore, identified as source of resistance in breeding programme.
2. PKV-TARA, AKT-8811, ICPL-87119, ICPL-20062 and ICPH-2740 emerged out as tolerant pigeonpea genotypes with high yield during the present investigation and can be included in IPM to avoid the development of selection pressure on the *H. armigera*.
3. Four types of trichomes, type A, type B, type C and type D, were identified on the calyxes and pods of the pigeonpea genotypes. Of



the four trichomes, type A and type B were found to be glandular, and type C and type D were non-glandular in nature. The variation in their structure and density led to variation in the levels of resistance in pigeonpea genotypes.

4. The secretions of glandular trichomes, type A and type B, on the flowers and pods of genotype acted as an attractants to *H. armigera* and thus contributing to susceptible reaction of genotypes.
5. The high density of non-glandular tnchomes, type C and type D, on the pods acting as deterrents to the *H. armigera* and causing the moths to exhibit non-preference for oviposition on the resistant genotypes and hindrance to the larva for boring into the pod.
6. Resistant/ moderately resistant genotypes could harbour low pest population in the field and equally possessed antibiosis mechanism by affecting adversely on biological parameters of *H. armigera*.
7. The biochemical factors greatly influenced the pest reaction in different genotypes. Significantly negative correlations were found between tannins flavonoids and phenol content and pest infestation.
8. The genotype ENT-11 and ICPHRL-4979-2 besides resistant check ICPL-332 of pigeonpea showed high level of resistance against *H. armigera* and hence were identified as the most potent source of genetic material to the breeder.
9. Thus, HPR in pigeonpea could be one of the tools to arrest the growth and development of *H. armigera* in further generations through antixenosis and antibiosis mechanism. However, multidisciplinary approach between entomologists and breeders is essential to promote this tactis.

## CHAPTER VI

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*Original not seen

# APPENDIX - I

## Weekly meteorological data from July 2011 to February 2012

| Met. week | Dates | Mean Temp ($^0$C) | Relative humidity % | Rain fall (mm) | Cumulative rainfall (mm) | Rainy Days |
|---|---|---|---|---|---|---|
| 27 | 2-8 July 2011 | 35.4 | 74 | 19.7 | 101.9 | 2 |
| 28 | 9-15 | 31.3 | 75 | 42.4 | 144.3 | 3 |
| 29 | 16-22 | 30.7 | 68 | 64.4 | 208.7 | 3 |
| 30 | 23-29 | 28 | 69 | 26.7 | 235.1 | 3 |
| 31 | 30-5 Aug. 2011 | 31 | 86.5 | 16.8 | 522.2 | 2 |
| 32 | 6-12 | 30 | 61 | 8.7 | 261.4 | 1 |
| 33 | 13-19 | 30 | 66 | 27.4 | 298.8 | 2 |
| 34 | 20-26 | 31 | 59 | 29.1 | 327.9 | 2 |
| 35 | 27-2 Sept. 2011 | 28 | 94 | 46.6 | 374.5 | 4 |
| 36 | 3-9 | 30 | 90 | 62.4 | 437.6 | 3 |
| 37 | 10-16 | 28 | 88 | 22.1 | 459.1 | 2 |
| 38 | 17-23 | 30 | 85 | 3.5 | 462.6 | 1 |
| 39 | 24-30 | 32 | 84 | - | 462.6 | - |
| 40 | 1-7 Oct. 2011 | 34 | 78 | - | 462.6 | - |
| 41 | 8-14 | 35 | 75 | - | 462.6 | - |
| 42 | 15-21 | 35 | 74 | - | 462.6 | - |
| 43 | 22-28 | 34.5 | 73 | - | 462.6 | - |
| 44 | 29-4Nov. 2011 | 32.1 | 70 | - | 462.6 | - |
| 45 | 5-11 | 33.2 | 65 | - | 462.6 | - |
| 46 | 12-18 | 33.5 | 63 | - | 462.6 | - |
| 47 | 19-25 | 30.6 | 63 | - | 462.6 | - |
| 48 | 26-2Dec. 2011 | 30.2 | 70 | - | 462.6 | - |
| 49 | 3-9 | 31.1 | 71 | - | 462.6 | - |
| 50 | 10-16 | 29.1 | 70 | - | 462.6 | - |
| 51 | 17-23 | 29.0 | 68 | - | 462.6 | - |
| 52 | 24-31 | 29.0 | 63 | - | 462.6 | - |
| 1 | 1-7 Jan. 2012 | 30.3 | 78 | - | 462.6 | - |
| 2 | 8-14 | 26.7 | 67 | - | 462.6 | - |
| 3 | 15-21 | 28 | 55 | - | 462.6 | - |
| 4 | 22-28 | 29.4 | 61 | - | 462.6 | - |
| 5 | 29-4 Feb. 2012 | 28.7 | 67 | 6.2 | 6.2 | 1 |
| 6 | 5-11 | 29.5 | 65 | - | 6.2 | - |
| 7 | 12-18 | 30 | 63 | - | 6.2 | - |
| 8 | 19-25 | 31 | 60 | - | 6.2 | - |

## APPENDIX - II

### Weekly meteorological data from July 2012 to February 2013

| Met. Week | Dates | Mean Temp ($^0$C) | Relative humidity % | Rain fall (mm) | Cumulative rainfall (mm) | Rainy Days |
|---|---|---|---|---|---|---|
| 27 | 2-8 July 2012 | 30.7 | 71 | 20.6 | 128 | 1 |
| 28 | 9-15 | 31.8 | 90 | 101 | 229.9 | 5 |
| 29 | 16-22 | 33.1 | 81 | 46.1 | 296.3 | 4 |
| 30 | 23-29 | 26.7 | 87 | 91.1 | 387.4 | 5 |
| 31 | 30-5 Aug. 2012 | 27.9 | 84 | 29 | 416.4 | 4 |
| 32 | 6-12 | 28.1 | 90 | 15.9 | 432.3 | 2 |
| 33 | 13-19 | 28.7 | 90 | 18.4 | 450.7 | 2 |
| 34 | 20-26 | 29.1 | 94 | 25.8 | 476.5 | 3 |
| 35 | 27-2 Sept. 2012 | 30.9 | 94 | 44 | 521.4 | 3 |
| 36 | 3-9 | 30.1 | 89 | 93.8 | 615.2 | 5 |
| 37 | 10-16 | 30.2 | 85 | 10.4 | 625.6 | 2 |
| 38 | 17-23 | 31.7 | 86 | 23.8 | 649.4 | 1 |
| 39 | 24-30 | 32.5 | 85 | 9.3 | 658.7 | 2 |
| 40 | 1-7 Oct. 2012 | 33.1 | 88 | 40.9 | 699.6 | 2 |
| 41 | 8-14 | 33.6 | 85 | 1.5 | 701.1 | - |
| 42 | 15-21 | 34.1 | 78 | - | 701.1 | - |
| 43 | 22-28 | 33 | 76 | - | 701.1 | - |
| 44 | 29-4Nov. 2012 | 31.4 | 75 | - | 701.1 | - |
| 45 | 5-11 | 32.1 | 72 | - | 701.1 | - |
| 46 | 12-18 | 31 | 73 | - | 701.1 | - |
| 47 | 19-25 | 30.7 | 73 | - | 701.1 | - |
| 48 | 26-2Dec. 2012 | 31.8 | 70 | - | 701.1 | - |
| 49 | 3-9 | 31.1 | 65 | - | 701.1 | - |
| 50 | 10-16 | 31.4 | 76 | - | 701.1 | - |
| 51 | 17-23 | 29.2 | 79 | - | 701.1 | - |
| 52 | 24-31 | 28.1 | 72 | - | 701.1 | - |
| 1 | 1-7 Jan. 2013 | 29.3 | 78 | 8 | 8.0 | 1 |
| 2 | 8-14 | 28 | 68 | - | 8.0 | - |
| 3 | 15-21 | 30.3 | 68 | - | 8.0 | - |
| 4 | 22-28 | 27.2 | 78 | 19.5 | 27.5 | 1 |
| 5 | 29-4 Feb. 2013 | 30 | 62 | - | 27.5 | - |
| 6 | 5-11 | 31.5 | 73 | - | 27.5 | - |
| 7 | 12-18 | 31 | 73 | 3.5 | 31.0 | 1 |
| 8 | 19-25 | 31 | 70 | - | 31.0 | - |

## APPENDIX-III

### Seasonal Incidence of *Helicoverpa armigera* Eggs 2011-12

| Genotype | MW41 | MW42 | MW43 | MW44 | MW45 | MW46 | MW47 | MW48 | MW49 | MW50 | MW51 | MW52 | MW1 | MW2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICPL-20139 | 0 | 0.4 | 0.6 | 0.8 | 0.8 | 1.2 | 2.3 | 2 | 2 | 1.6 | 1 | 0.6 | 0 | 0.2 | 13.5 |
| ICPL-20118 | 0 | 0.4 | 0.6 | 0.9 | 1.6 | 2 | 2.3 | 2.4 | 2 | 1.5 | 0.9 | 0.5 | 0 | 0 | 15.1 |
| ICPL-99004 | 0 | 0.5 | 0.8 | 1.4 | 1.8 | 2 | 2.6 | 2 | 1.8 | 1.4 | 0.8 | 0.4 | 0 | 0 | 15.5 |
| ICP-990016 | 0 | 0 | 0 | 0.2 | 0.6 | 0.6 | 0.6 | 2 | 1.4 | 1 | 0.6 | 0.4 | 0.2 | 0.1 | 7.7 |
| ENT-11 | 0 | 0 | 0 | 0.2 | 0.2 | 0.2 | 0.4 | 0.8 | 1 | 0.8 | 0.8 | 0.6 | 0 | 0 | 5 |
| ICP-10531 | 0 | 0.2 | 0.6 | 0.4 | 0.8 | 0.8 | 1.2 | 1.6 | 1.6 | 1.2 | 0.9 | 0.6 | 0.1 | 0 | 10 |
| ICP-13198 | 0 | 0 | 0.5 | 0.4 | 0.6 | 0.6 | 1.3 | 1.8 | 1.5 | 1.5 | 0.8 | 0.5 | 0 | 0 | 9.5 |
| ICPHRL-4978-5 | 0 | 0 | 0.6 | 0.4 | 0.6 | 1.2 | 1.2 | 2 | 2 | 1.4 | 1 | 0.6 | 0 | 0 | 11 |
| ICPHRL-4979-2 | 0 | 0 | 0 | 0.2 | 0.4 | 0.6 | 1 | 1.8 | 1.4 | 1.3 | 0.7 | 0.4 | 0 | 0 | 7.8 |
| ICPHRL-4985-1 | 0 | 0.2 | 0.6 | 1 | 1.6 | 2 | 2.5 | 2 | 1.8 | 1.3 | 1 | 0.8 | 0.1 | 0.1 | 15 |
| ICPHRL-4985-10 | 0 | 0.2 | 0.2 | 0.6 | 0.7 | 0.6 | 1 | 2 | 1.5 | 1.5 | 0.9 | 0.6 | 0 | 0 | 9.8 |
| ICPHRL-4989-7 | 0 | 0.2 | 0.6 | 1 | 1.8 | 2.2 | 1.3 | 2 | 2 | 2 | 1.2 | 0.8 | 0.3 | 0 | 15.4 |
| ICPL-20062 | 0 | 0 | 0 | 0.2 | 0.4 | 0.8 | 1.1 | 1.5 | 1.6 | 1.4 | 1 | 0.8 | 0 | 0 | 8.8 |
| ICPL-332 | 0 | 0 | 0 | 0.2 | 0.4 | 0.4 | 1 | 1.2 | 1.2 | 1 | 0.8 | 0.4 | 0 | 0 | 6.6 |
| ICPL-909 | 0 | 0 | 0.6 | 0.4 | 0.4 | 0.8 | 1.4 | 1.4 | 1.5 | 1.2 | 1 | 0.6 | 0 | 0 | 9.3 |
| ICPL-97253 | 0 | 0 | 0.2 | 0.5 | 0.8 | 0.6 | 1.2 | 1.6 | 1.6 | 1.2 | 1.1 | 0.6 | 0 | 0 | 9.4 |
| PPE-45-2 | 0 | 0 | 0.2 | 0.2 | 0.6 | 0.9 | 1 | 1 | 1.8 | 1.5 | 1.1 | 0.8 | 0 | 0 | 9.1 |
| ICPL-87 | 0.2 | 0.4 | 0.8 | 1.4 | 1.6 | 2.3 | 2.6 | 2.6 | 2.2 | 1.2 | 0.4 | 0.1 | 0 | 0 | 15.8 |
| ICPL-87119 | 0 | 0 | 0.2 | 0.4 | 0.8 | 1.2 | 1.5 | 2.5 | 2.5 | 2.3 | 1 | 0.6 | 0.2 | 0.1 | 13.3 |
| PKV-TARA | 0 | 0.3 | 0.6 | 0.9 | 1.2 | 1.4 | 1.4 | 2.6 | 1.8 | 1.3 | 1 | 0.5 | 0.2 | 0 | 13.2 |
| AKT-8811 | 0 | 0.4 | 0.4 | 0.8 | 1.2 | 1.4 | 1.8 | 2.2 | 2 | 1 | 0.8 | 0.6 | 0 | 0 | 12.6 |
| BSMR-736 | 0 | 0 | 0.4 | 0.5 | 1.2 | 1.4 | 2 | 2.4 | 2.4 | 1.9 | 1 | 0.8 | 0.1 | 0 | 14.1 |
| ICPH-2071 | 0 | 0 | 0.4 | 0.6 | 0.6 | 1 | 2 | 2.2 | 2.6 | 2 | 1.2 | 0.9 | 0.2 | 0 | 13.7 |
| ICPH-2740 | 0 | 0 | 0.4 | 0.4 | 0.8 | 1.2 | 1.5 | 2 | 2.8 | 1.9 | 1 | 0.9 | 0.2 | 0 | 13.1 |

## APPENDIX-III

### Seasonal Incidence of *Helicoverpa armigera* Larva 2011-12

| Genotype | MW41 | MW42 | MW43 | MW44 | MW45 | MW46 | MW47 | MW48 | MW49 | MW50 | MW51 | MW52 | MW1 | MW2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICPL-20139 | 0 | 0 | 0.1 | 0.2 | 0.6 | 0.6 | 0.8 | 1 | 1 | 0.8 | 0.6 | 0.4 | 0 | 0 | 6.1 |
| ICPL-20118 | 0 | 0 | 0 | 0.3 | 0.3 | 0.7 | 1 | 1 | 1 | 1.5 | 0.8 | 0.4 | 0 | 0 | 7 |
| ICPL-99004 | 0 | 0 | 0.1 | 0.2 | 0.5 | 0.9 | 1.2 | 1.5 | 1 | 0.9 | 0.6 | 0.5 | 0 | 0 | 7.4 |
| ICP-990016 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.3 | 0.6 | 1 | 1 | 0.6 | 0.2 | 0.1 | 0 | 3.9 |
| ENT-11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.3 | 0.5 | 0.4 | 0.4 | 0.1 | 0 | 1.8 |
| ICP-10531 | 0 | 0 | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.6 | 0.6 | 0.9 | 0.6 | 0.4 | 0.2 | 0 | 4.3 |
| ICP-13198 | 0 | 0 | 0 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 0.7 | 0.8 | 0.7 | 0.2 | 0.1 | 0 | 3.9 |
| ICPHRL-4978-5 | 0 | 0 | 0 | 0.2 | 0.1 | 0.3 | 0.6 | 0.9 | 1.5 | 1 | 0.9 | 0.6 | 0.2 | 0 | 6.3 |
| ICPHRL-4979-2 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.3 | 0.6 | 0.8 | 0.8 | 0.6 | 0.3 | 0.1 | 0 | 3.6 |
| ICPHRL-4985-1 | 0 | 0 | 0 | 0.2 | 0.5 | 0.7 | 0.6 | 0.9 | 0.9 | 1.2 | 1 | 0.8 | 0.2 | 0 | 7 |
| ICPHRL-4985-10 | 0 | 0 | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.6 | 1 | 1.1 | 0.8 | 0.6 | 0 | 0 | 5.1 |
| ICPHRL-4989-7 | 0 | 0 | 0 | 0.2 | 0.4 | 0.7 | 1.2 | 0.7 | 1.2 | 1 | 1 | 0.5 | 0.2 | 0 | 7.1 |
| ICPL-20062 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.3 | 0.6 | 1 | 1.2 | 0.9 | 0.5 | 0.2 | 0 | 4.9 |
| ICPL-332 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.5 | 0.6 | 0.5 | 0.5 | 0.3 | 0.1 | 0 | 2.7 |
| ICPL-909 | 0 | 0 | 0 | 0.1 | 0.1 | 0.2 | 0.3 | 0.6 | 0.7 | 0.9 | 1 | 0.5 | 0 | 0 | 4.4 |
| ICPL-97253 | 0 | 0 | 0 | 0 | 0.2 | 0.3 | 0.2 | 0.7 | 0.6 | 0.9 | 0.5 | 0.6 | 0.2 | 0 | 4.2 |
| PPE-45-2 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.4 | 0.5 | 0.7 | 0.6 | 0.8 | 0.6 | 0.2 | 0 | 4 |
| ICPL-87 | 0 | 0.1 | 0.1 | 0.4 | 1 | 1.2 | 1.3 | 1.4 | 1.4 | 1 | 0.6 | 0.2 | 0 | 0 | 8.7 |
| ICPL-87119 | 0 | 0 | 0 | 0 | 0.2 | 0.4 | 0.4 | 0.8 | 1.2 | 1.5 | 1 | 0.6 | 0.2 | 0 | 6.3 |
| PKV-TARA | 0 | 0 | 0 | 0.2 | 0.2 | 0.5 | 0.8 | 1 | 1.5 | 1 | 1.2 | 0.4 | 0.1 | 0 | 6.9 |
| AKT-8811 | 0 | 0 | 0 | 0.3 | 0.4 | 0.7 | 0.7 | 1 | 1.2 | 1 | 0.6 | 0.4 | 0.2 | 0 | 6.5 |
| BSMR-736 | 0 | 0 | 0 | 0 | 0.3 | 0.6 | 1 | 1.2 | 1.4 | 1.6 | 1.2 | 0.8 | 0.2 | 0 | 8.3 |
| ICPH-2071 | 0 | 0 | 0 | 0 | 0.2 | 0.4 | 0.6 | 1 | 1.2 | 1.3 | 1.2 | 0.6 | 0.3 | 0 | 6.8 |
| ICPH-2740 | 0 | 0 | 0 | 0 | 0.2 | 0.3 | 0.6 | 0.8 | 1.2 | 1.6 | 1 | 0.6 | 0.3 | 0 | 6.6 |

## APPENDIX-III

### Seasonal Incidence of *Helicoverpa armigera* Eggs 2012-13

| Genotype | MW41 | MW42 | MW43 | MW44 | MW45 | MW46 | MW47 | MW48 | MW49 | MW50 | MW51 | MW52 | MW1 | MW2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICPL-20139 | 0 | 0.5 | 0.6 | 0.8 | 1 | 1.5 | 1 | 1.8 | 2.5 | 2 | 1 | 0.8 | 0.2 | 0 | 13.7 |
| ICPL-20118 | 0.3 | 0.4 | 0.3 | 1 | 1.2 | 2 | 1.5 | 1.8 | 2.2 | 2.2 | 2 | 1 | 0.3 | 0 | 16.2 |
| ICPL-99004 | 0.4 | 0.8 | 1 | 1 | 1.5 | 1.5 | 1.5 | 1.8 | 2.2 | 2.5 | 2 | 1 | 0.5 | 0 | 17.7 |
| ICP-990016 | 0 | 0.2 | 0.1 | 0.3 | 0.4 | 0.8 | 1 | 1.3 | 1.6 | 1.9 | 1.4 | 1 | 0.2 | 0 | 10.2 |
| ENT-11 | 0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.5 | 0.6 | 0.8 | 1 | 1.2 | 1 | 0.6 | 0.3 | 0 | 6.5 |
| ICP-10531 | 0 | 0.2 | 0.2 | 0.6 | 0.9 | 1.2 | 1.4 | 2 | 1.5 | 1 | 0.8 | 0.5 | 0.2 | 0 | 10.5 |
| ICP-13198 | 0 | 0 | 0.3 | 0.6 | 0.6 | 1 | 1.2 | 1.5 | 1.9 | 1.4 | 1.5 | 0.8 | 0.1 | 0 | 10.9 |
| ICPHRL-4978-5 | 0.4 | 0.8 | 1 | 1 | 1.5 | 1.8 | 1.5 | 1.5 | 2.2 | 2.2 | 1.9 | 0.8 | 0.1 | 0.1 | 16.8 |
| ICPHRL-4979-2 | 0 | 0.2 | 0.2 | 0.5 | 0.8 | 0.8 | 1 | 1.2 | 1.8 | 1.5 | 1.2 | 0.6 | 0 | 0 | 9.8 |
| ICPHRL-4985-1 | 0.2 | 0.4 | 0.8 | 1 | 1.2 | 1.6 | 2 | 2 | 2.5 | 2.2 | 1.8 | 0.9 | 0.2 | 0.1 | 16.9 |
| ICPHRL-4985-10 | 0.2 | 0.3 | 0.2 | 0.6 | 0.8 | 1 | 1.2 | 1.5 | 1.8 | 1.5 | 1.3 | 0.9 | 0.2 | 0 | 11.5 |
| ICPHRL-4989-7 | 0.2 | 0.4 | 0.8 | 0.9 | 0.9 | 1.5 | 1.8 | 2 | 2.1 | 1.3 | 1 | 0.6 | 0.3 | 0 | 13.8 |
| ICPL-20062 | 0 | 0.2 | 0.2 | 0.6 | 0.6 | 1.4 | 1.5 | 1.3 | 1.6 | 1.6 | 1.3 | 0.5 | 0.1 | 0 | 10.9 |
| ICPL-332 | 0 | 0.2 | 0.2 | 0.2 | 0.5 | 1.2 | 1.3 | 1.2 | 1.8 | 2 | 1.5 | 0.7 | 0.2 | 0 | 11 |
| ICPL-909 | 0 | 0.1 | 0.2 | 0.4 | 0.7 | 1 | 1.2 | 1.5 | 1.8 | 2 | 1.6 | 0.8 | 0.2 | 0 | 11.5 |
| ICPL-97253 | 0 | 0.1 | 0.2 | 0.4 | 0.6 | 1 | 1.2 | 1.8 | 1.8 | 2 | 1.5 | 1 | 0.5 | 0 | 12.1 |
| PPE-45-2 | 0 | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.5 | 2 | 1.2 | 1 | 0.8 | 0 | 10.7 |
| ICPL-87 | 0.8 | 0.8 | 1.2 | 1.4 | 2 | 2.4 | 2.5 | 2.4 | 2 | 1.8 | 0.8 | 0.1 | 0 | 0 | 18.2 |
| ICPL-87119 | 0.2 | 0.3 | 0.6 | 0.6 | 0.8 | 1 | 1.5 | 1.8 | 2.2 | 2.2 | 1.6 | 0.6 | 0.1 | 0 | 13.5 |
| PKV-TARA | 0.4 | 0.4 | 0.4 | 0.8 | 1 | 1.5 | 1.6 | 2 | 2 | 2.5 | 2 | 1 | 0.3 | 0 | 15.9 |
| AKT-8811 | 0.6 | 0.6 | 0.6 | 1.2 | 1.5 | 2.2 | 1.3 | 1.2 | 1.6 | 1 | 0.7 | 0.1 | 0 | 0 | 12.6 |
| BSMR-736 | 0.2 | 0.3 | 0.4 | 1 | 1.2 | 1.6 | 2 | 2 | 2.2 | 2.4 | 2 | 1 | 0.5 | 0 | 16.8 |
| ICPH-2071 | 0.2 | 0.2 | 0.4 | 0.8 | 1 | 1 | 1.5 | 1.5 | 2 | 2.2 | 2 | 1.2 | 0.5 | 0 | 14.5 |
| ICPH-2740 | 0.2 | 0.2 | 0.2 | 0.6 | 0.9 | 1.2 | 1.4 | 1.9 | 1.9 | 2.1 | 1.9 | 1 | 0.4 | 0 | 13.9 |

## APPENDIX-III

### Seasonal Incidence of *Helicoverpa armigera* Larva 2012-13

| Genotype | MW41 | MW42 | MW43 | MW44 | MW45 | MW46 | MW47 | MW48 | MW49 | MW50 | MW51 | MW52 | MW1 | MW2 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICPL-20139 | 0 | 0 | 0.2 | 0.3 | 0.3 | 0.6 | 0.9 | 0.4 | 0.8 | 1 | 1.2 | 0.6 | 0.1 | 0 | 6.4 |
| ICPL-20118 | 0 | 0.1 | 0.1 | 0.2 | 0.5 | 0.7 | 0.9 | 0.8 | 1 | 1.3 | 1.4 | 1 | 0.4 | 0.1 | 8.5 |
| ICPL-99004 | 0 | 0.2 | 0.3 | 0.5 | 0.6 | 0.7 | 0.6 | 0.8 | 1 | 1.2 | 1.3 | 0.9 | 0.6 | 0.2 | 8.9 |
| ICP-990016 | 0 | 0 | 0 | 0 | 0.1 | 0.2 | 0.3 | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.5 | 0 | 4.7 |
| ENT-11 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.6 | 0.5 | 0.2 | 0 | 2.3 |
| ICP-10531 | 0 | 0 | 0.1 | 0.1 | 0.3 | 0.4 | 0.7 | 0.8 | 1 | 0.8 | 1 | 0.9 | 0.2 | 0 | 6.3 |
| ICP-13198 | 0 | 0 | 0 | 0 | 0.2 | 0.3 | 0.6 | 0.7 | 0.7 | 1.1 | 0.9 | 1 | 0.3 | 0 | 5.8 |
| ICPHRL-4978-5 | 0 | 0.2 | 0.3 | 0.6 | 0.6 | 0.8 | 1 | 0.7 | 0.7 | 1.2 | 1.2 | 0.8 | 0.2 | 0 | 8.3 |
| ICPHRL-4979-2 | 0 | 0 | 0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.5 | 0.6 | 1 | 0.6 | 0.8 | 0.1 | 0 | 4.5 |
| ICPHRL-4985-1 | 0 | 0 | 0.1 | 0.2 | 0.4 | 0.7 | 0.8 | 0.9 | 0.8 | 1.1 | 1 | 0.9 | 0.2 | 0 | 7.1 |
| ICPHRL-4985-10 | 0 | 0 | 0.1 | 0 | 0.2 | 0.3 | 0.7 | 0.7 | 0.9 | 1 | 0.7 | 0.6 | 0.1 | 0 | 5.3 |
| ICPHRL-4989-7 | 0 | 0 | 0.1 | 0.3 | 0.3 | 0.4 | 0.8 | 1 | 1.2 | 1.3 | 0.9 | 0.6 | 0.3 | 0.1 | 7.3 |
| ICPL-20062 | 0 | 0 | 0 | 0.1 | 0.2 | 0.3 | 0.9 | 0.8 | 0.8 | 0.8 | 0.9 | 0.6 | 0.1 | 0 | 5.5 |
| ICPL-332 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.4 | 0.5 | 0.5 | 0.8 | 1 | 0.6 | 0.1 | 0 | 4.1 |
| ICPL-909 | 0 | 0 | 0 | 0 | 0.1 | 0.2 | 0.6 | 0.5 | 0.8 | 1 | 1.2 | 0.9 | 0.2 | 0 | 5.5 |
| ICPL-97253 | 0 | 0 | 0 | 0 | 0.1 | 0.2 | 0.6 | 0.6 | 1 | 0.7 | 1 | 0.8 | 0.6 | 0 | 5.6 |
| PPE-45-2 | 0 | 0 | 0 | 0 | 0.1 | 0.2 | 0.5 | 0.8 | 0.6 | 0.7 | 1 | 0.7 | 0.6 | 0.2 | 5.4 |
| ICPL-87 | 0.2 | 0.3 | 0.4 | 0.9 | 1 | 1 | 1.3 | 1.4 | 1.2 | 0.8 | 0.9 | 0.3 | 0 | 0 | 9.7 |
| ICPL-87119 | 0 | 0 | 0.1 | 0.1 | 0.3 | 0.3 | 0.6 | 1 | 1.1 | 1.2 | 1.3 | 1 | 0.2 | 0 | 7.2 |
| PKV-TARA | 0 | 0.1 | 0.1 | 0.1 | 0.3 | 0.6 | 0.8 | 0.9 | 1.1 | 1.2 | 1.6 | 0.9 | 0.6 | 0.1 | 8.4 |
| AKT-8811 | 0 | 0.2 | 0.2 | 0.2 | 0.9 | 1 | 1.4 | 0.8 | 0.6 | 0.8 | 0.4 | 0.2 | 0 | 0 | 6.7 |
| BSMR-736 | 0 | 0 | 0.1 | 0.1 | 0.6 | 0.9 | 0.8 | 1.1 | 0.9 | 1.2 | 1.3 | 0.8 | 0.5 | 0.1 | 8.4 |
| ICPH-2071 | 0 | 0 | 0 | 0.1 | 0.2 | 0.5 | 0.6 | 0.9 | 0.8 | 0.9 | 1.4 | 1 | 0.5 | 0.1 | 7 |
| ICPH-2740 | 0 | 0 | 0.1 | 0.1 | 0.3 | 0.3 | 0.7 | 0.7 | 1 | 1 | 1.1 | 0.8 | 0.4 | 0.2 | 6.7 |

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8. Filed of interest (in which you desire to work) : Research in Integrated Pest Management
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