VARIETAL SCREENING AND INSECTICIDAL EVALUATION AGINST *MARUCA VITRATA* (Geyer) IN PIGEONPEA

By

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B.Sc. (Ag.)

THESIS SUBMITTED TO THE
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CERTIFICATE

This is to certify that the thesis entitled "**VARIETAL SCREENING AND INSECTICIDAL EVALUATION AGINST *MARUCA VITRATA* (Geyer) IN PIGEONPEA**" submitted in partial fulfillment of the requirements for the degree of "**MASTER OF SCIENCE IN AGRICULTURE**" of the Acharya N. G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mrs. V. SUNITHA** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

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

K. vijaya Lakshmi

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CERTIFICATE

Mrs. V. SUNITHA has satisfactorily prosecuted the course of research and that the thesis entitled **"VARIETAL SCREENING AND INSECTICIDAL EVALUATION AGINST *MARUCA VITRATA* (Geyer) IN PIGEONPEA"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by her for a degree of any University.

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Place : Hyderabad

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Major Advisor

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DECLARATION

I, **V. SUNITHA** hereby declare that the thesis entitled **"VARIETAL SCREENING AND INSECTICIDAL EVALUATION AGINST *MARUCA VITRATA* (Geyer) IN PIGEONPEA"** submitted to Acharya N. G. Ranga Agricultural University for the degree of **"MASTER OF SCIENCE IN AGRICULTURE"** is the result of original research work done by me. I also declare that the thesis or any part thereof has not been published earlier in any manner.

Date :
Place : Hyderabad

V. Sunitha
(V. SUNITHA)

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	:	Degree centigrade
%	:	Per cent
@	:	At the rate of
*	:	Signaficant at 5%
**	:	Significant at 1 %
/	:	Per
AD	:	Approximate digestability
a.i.	:	Active ingredient
CD	:	Critical difference
CI	:	Consumption index
cm	:	Centimeter
CV	:	Coefficient of variation
EC	:	Emulsifiable concentrate
ECD	:	Efficiency of conversion of digested food into body matter
ECI	:	Efficiency of conversion of ingested food into body matter
et al.,	:	and others
fig.	:	Figure
ha	:	Hectare
hrs	:	hours
IAC	:	ICRISAT Asia Centre
ICPL	:	ICRISAT Pigeonpea line
ICRISAT	:	International Crops Research Institute for the Semi Arid Tropics
ie.,	:	That is

IPM	:	Integrated Pest Management
l	:	Liter
m	:	Meter
ml	:	Milli litre
NFE	:	Neem Fruit Extract
NSKE	:	Neem Seed Kernal Extract
NS	:	Not significant
r	:	Correlation coefficient
r^2	:	Regression coefficient
rms	:	Residual mean square
SE	:	Standard error difference of treatment. means
SL	:	Soluble liquid
S.No.	:	Serial number
viz.,	:	Namely

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ABSTRACT

The present study was under taken on the "varietal screening and insecticidal evaluation against *Maruca vitrata* (Geyer) in pigeonpea" at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh during 2004-2005 crop season. Six selected short duration pigeonpea genotypes *viz.*, ICPL 98001, ICPL 98002, ICPL 98003, ICPL 98008, ICPL 98012 and ICPL 88034 were tested against *M. vitrata* in the field, greenhouse and laboratory conditions. The relative efficacy of six insecticides were evaluated against 3rd instar larvae of *M. vitrata* under laboratory conditions.

The pod damage by *M. vitrata* on pigeonpea genotypes in the field ranged from 5.80 to 68.00 per cent. Based on the resistance rating, ICPL 98003 and ICPL 98008 were categorized as highly resistant and

ICPL 98012 as moderately resistant genotype. The genotypes ICPL 98001 and ICPL 98002 showed intermediate reaction and ICPL 88034 was categorized as susceptible genotype.

Greenhouse and laboratory studies showed less consumption of food and reduced larval and pupal weights of *M. vitrata* when reared on highly resistant genotypes (ICPL 98003 and ICPL 98008), while the larvae reared on the susceptible genotype ICPL 88034 consumed more food, showed more larval and pupal weights and recorded highest growth rate as compared to the highly resistant genotypes.

The morphological and chemical parameters of the genotypes *viz.*, trichome length, density, pod wall thickness, sugars, proteins and phenols were responsible for resistance / susceptibility of the genotypes to *M. vitrata*.

The laboratory studies conducted with newer and ecofriendly insecticides against *M. vitrata* revealed that the indoxacarb and spinosad were highly effective at recommended doses. The biopesticides, *Bacillus thurigiensis* and *Metarhizium anisopliae* showed moderate efficacy and the botanical insecticide neem fruit extract was least effective to *M. vitrata*.

CHAPTER - I

INTRODUCTION

Pigeonpea, *Cajanus cajan* (L) Mill is an important grain legume and occupies the second largest area among the various pulse crops grown in India. It is a staple diet in most parts of India and is consumed as green peas as well as dry seeds. (Tabo *et al.*, 1995). Its importance to semi-arid cropping systems is due to its efficient nitrogen-fixing ability, tolerance to drought and contribution to soil organic matter. Pigeonpea is grown on relatively marginal soils and has the potential to provide upto three crops per year (Ranga Rao and shanower, 1999). In India pigeonpea is grown on 3.5 million hectares with an annual production of 2.4 million tonnes and accounts for 85 to 90% of the world area under pigeonpea (FAO, 2005).

Among the several factors responsible for low yields of pigeonpea, insect pests are major limiting factors. More than 200 species of insects live and feed on pigeonpea, relatively few cause heavy annual losses (Reed and Lateef, 1990). The few pests however, can be devastating in epidemic situations. Among the insects feeding on reproductive parts, gram pod borer *Helicoverpa armigera,* spotted pod borer *Maruca vitrata* and redgram pod fly *Melanogromyza obtusa* are of prime importance.

During recent years due to introduction of short duration pigeonpea cultivars, the incidence of *M. vitrata* has been aggravated as flowering of these varieties occur during periods of high humidity and moderate temperature which is congenial for the development of pest (Sharma *et al.*, 1999).

M. vitrata larvae feed on flowers, buds and pods by webbing them. This typical feeding habit protects the larvae from natural enemies and other adverse factors including insecticides. Larvae move from one flower to another and each may consume 4-6 flowers before larval development is completed. Third instar larvae are capable of boring in to the pods, and occasionally into peduncles and stems (Taylor, 1967).

In pigeonpea, losses due to *M. vitrata* have been estimated to be $US 30 million annually (ICRISAT 1992). Vishakantaiah and Jagadeesh Babu (1980) observed the infestation of *Maruca* on pigeonpea varying between 9 and 51% at Banglore, Karnataka. Singh (1999) reported 70 –80 % yield loss in pigeonpea, whereas it was 17-53% in cowpea (Liao and Lin, 2000) and 100% in urd bean (Giraddi *et al* ., 2000).

M. vitrata was controlled primarily through use of chemical insecticides (Booker 1965; Dina 1979,1988). But dependence on only chemicals may lead to the problems such as development of resistance, outbreak of secondary pests and pesticide residues in agricultural produce. To avoid this situation it is very essential to follow the concept

of integrated pest management (IPM). The primary components of IPM are the use of resistant cultivars, conservation of natural enemies and safe use of chemicals. Use of pest resistant cultivars is an effective, cheap and environmentally safe component of IPM programme. Screening of cultivars under field condition is often difficult due to lack of uniform infestation or low levels of infestation. This problem can be avoided through artificial infestation of the test plants under greenhouse conditions. No serious attempts have been made in the past to screen pigeonpea varieties for resistance to *M. vitrata* under uniform infestation.

Several plant characters have been postulated to offer resistance to the pod borers (Tayo, 1988, Oghiakhe *et al.*, 1991a, 1991b, 1992a). However data on the role of plant characters that provide resistance to *M. vitrata* are inconclusive. Among the plant characters trichomes and trichome exudates on plant surfaces play an important role in the host selection process of insect herbivores (Bernays and Chapman, 1994). The type of trichomes and their orientation, density and length have been correlated with reduced insect damage in several crops (Jeffree, 1986; David and Easwaramoorthy, 1988; Peter 1995). At present little is known about the effect of trichomes in pigeonpea resistance to *M. vitrata*. Most of the suggestions about their efficacy in controlling the pest have not been supported by any data (Oghiakhe, 1990).

The biochemical constituents present in quantities and proportion to each other in host plants have been reported to exert profound influence on the growth, survival and reproduction of insects in various ways (Painter 1958, Panda and Khush 1995). The secondary plant substances present in pigeonpea which affect the plant suitability to other insects are also likely to affect the growth and development of *M. vitrata.*

Considerable number of insecticides have been tested and a few of them were found effective against pod borer complex including *Maruca* on cowpea and pigeonpea (Degri and Choudhary 1998 and Sahoo and Senapati 2000). But repeated use of these chemicals result in the development of resistance to insecticides. Recently the management was focused on the use of safer chemicals and microbial pesticides. After the introduction and availability of the new molecules such as indoxacarb and spinosad, which were tested and found effective against the key polyphagous pests like *Helicoverpa armigera* and *Spodoptera litura,* but the studies on the effect of these new molecules on *M. vitrata* were inconclusive. So there is every need to study their effect on this species. Hence, the present study was mainly focused on the development of effective management strategies for *M.vitrata* with the following objectives.

1. To screen some of the promising short duration pigeonpea genotypes under field, green house and laboratory conditions against *M. vitrata.*

2. To study the role of morphological and biochemical factors offering resistance / susceptibility of pigeonpea genotypes to *M.vitrata.*

3. To test the efficacy of selected insecticides against *M. vitrata* under laboratory conditions.

CHAPTER - III

MATERIALS AND METHODS

Studies on screening of some promising pigeonpea genotypes of against *Maruca vitrata* (Geyer) were conducted under field, greenhouse and laboratory conditions. The efficacy of certain new insecticides were also evaluated against M. vitrate under labaratory conditions at ICRISAT Asia center, Patancheru, Hyderabad, Andhra Pradesh during 2004-2005 crop season. The materials used and methods employed in the present studies are presented here under.

3.1 SCREENING OF PIGEONPEA GENOTYPES AGAINST *MARUCA VITRATA*

For varietal screening studies six pigeonpea genotypes i.e. ICPL 98001, ICPL98002, ICPL98003, ICPL98008, ICPL98012, ICPL88034, were selected and screened under field conditions as well as under artificial infestation in the green house and laboratory for resistance to *vitrata* during *kharif* season from June 2005 to October 2005 at ICRISAT, Asia center. The various screening techniques followed were described below .

3.1.1 Screening of pigeonpea genotypes for resistance to *Maruca vitrata* under field conditions

Table-1 :Characterization of selected pigeonpea genotypes used in the study

S. No.	Genotype	Growth habit	Days to flower	Days to maturity
1.	ICPL 98001	Determinate	54	108
2.	ICPL 98002	Determinate	54	108
3.	ICPL 98003	Determinate	54	108
4.	ICPL 98008	In determinate	64	110
5.	ICPL 98012	In determinate	66	112
6.	ICPL 88034	In determinate	61	115

Six pigeonpea genotypes i.e. ICPL 98001, ICPL98002, ICPL98003, ICPL98008, ICPL98012, ICPL 88034, were planted on 28th june 2005 in randomized block design (fig 1). Each cultivar was sown in two rows of each measuring 3m length with a spacing of 60 x 10 cm. Recommended agronomic practices were followed to raise the crop except the plant protection measures. Observations on maruca infestation recorded during the peak infestation of *Maruca* when some of the lines were completely damaged. Entries showing more than 40 percent damage were considered to be susceptible and those showing less than 10 percent damage were considered to be resistant (Bindra and Jokhmola (1967) and Sahoo *et al.* (2000).

3.1 MASS REARING OF *MARUCA VITRATA* ON ARTIFICIAL DIET

To obtain required number insects of the appropriate stage at a given moment of plant development, specific artificial rearing techniques are necessary. The techniques of mass rearing on artificial diet was used form in the present study. Field collected fifth instar larvae of SPB *Maruca vitrata* were utilized for maintaining the mass culture. The larvae were reared in clean and sterilized glass troughs of 13 x 30 cm on artificial diet. Pupae obtained were kept in a plastic container with cotton padding for adult emergence.

Newly emerged adults were released into cages of 60 x 30 x 90 cm size and were fed with 10 % sugar solution soaked cotton swabs that were hanging down from the cages. Fresh tender twigs and inflorescence of pigeonpea were placed in water filled conical flasks whose mouths were plugged with cotton. The flasks with such inflorescence were kept in cages for egg laying. The inflorescence were changed daily. The flowers, flower buds and tender leaves were examined for the presence of egg masses. The collected egg masses were placed on moist (whatmann no. 41) filter paper kept in Petri plates. After hatching the larvae were maintained on artificial diet as developed Ochieng *et al.* (1981). The diet was regularly replenished with the freshly prepared diet.

Method of preparation of Artificial diet:

The details of required ingradients for preparing 1 liter of diet

Water (for blending)	500 ml
Chickpea flour	100 g
Pigeonpea leaf powder	12.5 g
Ascorbic acid	6.25 g
Methyl para hydroxy benzoate	1.58 g
Sorbic acid	0.96 g

Sugar	15 g
Cholin chloride (15 %)	7.4 ml
KOH (4 M)	5.5 gm
Wheat germ	31.8 gm
Wesson salt mix	10.6 gm
Acetic acid (25%)	12.5 ml
Formaldehyde (10%)	6.5 ml
Aureomycin (5% a.i)	2.75 g
Vitamin solution	7.50 ml
Water (for blending Agar)	500 ml
Agar	14.80 g

Ingredients such as chickpea flour, pigeonpea leaf powder, ascorbic acid, Methyl parahydroxy benzoate, sorbic acid, sugar, cholin chloride (5%), KOH, wheatgerm, wesson salt mix, Acetic acid, formaldehyde, Aureomycin and vitamin solution were added to 500 ml of water and blended for 2 to 3 minutes. Another 500 ml water was boiled and Agar was added to it with thorough mixing. After little cooling this mixture was added to earlier mixture in the blender and

Fig.1 FIELD LAY OUT

T_4	T_1	T_6	T_3
T_1	T_5	T_3	T_1
T_2	T_3	T_5	T_4
T_5	T_6	T_1	T_6
T_3	T_4	T_2	T_2
T_6	T_2	T_4	T_5

Location : RP 7B (south); **Date of sowing: 29 – 06 – 2005;** **Plot size: 1.8 m^2**

Replications : 4; **Treatments: 6**

T_1 = ICPL 98001; T_2 = ICPL 98002; T_3 = ICPL 98003; T_4 = ICPL 98008; T_5 = ICPL 98012; T_6 = ICPL 88034

Plate 2 : Pigeonpea genotypes at 50 per cent flowering stage used for screening against *Maruca vitrata* in the greenhouse

Plate 3 : Screening of pigeonpea genotypes against *Maruca vitrata* in the greenhouse using wire framed cage

blended for 2-3 minutes. This diet mixture was poured into trays and was used for rearing *vitrata* larvae.

3.2 VARIETAL SCREENING OF PIGEONPEA AGAINST *MARUCA VITRATA*

3.2.1 Methods used in pigeonpea screening for resistance:

3.2.1.1 Green house screening

Treatments 6 Replications 4

Treatment 1 ICPL 88034

Treatment 2 ICPL 98001

Treatment 3 ICPL 98002

Treatment 4 ICPL 98003

Treatment 5 ICPL 98008

Treatment 6 ICPL 98012

Cage technique developed by Sharma H.C was used to screen pigeonpea genotypes for resistance to *Maruca vitrata* six pigeonpea genotypes were selected and each was replicated four times. Each genotype was sown in twenty pots at the rate of one plant per pot.

At the time of 50% flowering each plant was infested with 10 first instar larvae and covered with a muslin cloth bag placed around a

wire framed cage. The caged plants were evaluated for insect damage at 15 days after infestation .

Observations were taken on larval mortality, larvae weight gain, number of flowers per plant, number of flowers dropped, number of healthy and damaged pods and grain yield in infected and uninfested plants.

3.2.1.2 field screening:

Six pigeonpea cultivars were field tested for their resistance / tolerance to *Maruca vitrata*. Each cultivar was sown in two rows of each 3m length with a spacing 10x60cm. Recommended agronomic practices were followed to raise the crop. Observations were recorded at the time of peak infestation of *Maruca vitrata* when some of the lines were completely damaged. Entries showing more than 40 percent damage were considered to be susceptible and those showing less than 10 percent damage were considered to be resistant (Bindra and Jokhmola (1967)) and Sahoo *et al.* (2000).

3.2.1.3 Laboratory screening

Tender pigeonpea twigs at 50% flowering stage were collected from six varieties were collected from the field and these twigs were kept in conical flask filled with water and their mouth plugged with cotton .Ten first instar larvae of Maruca vitrata were released on these

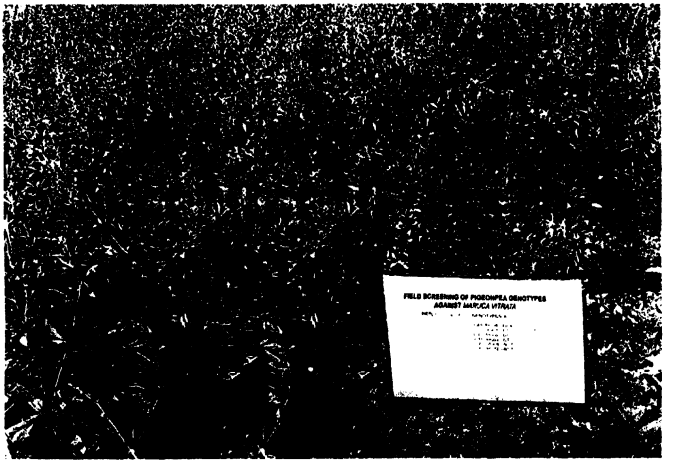


Plate 1 : Experimental field layout

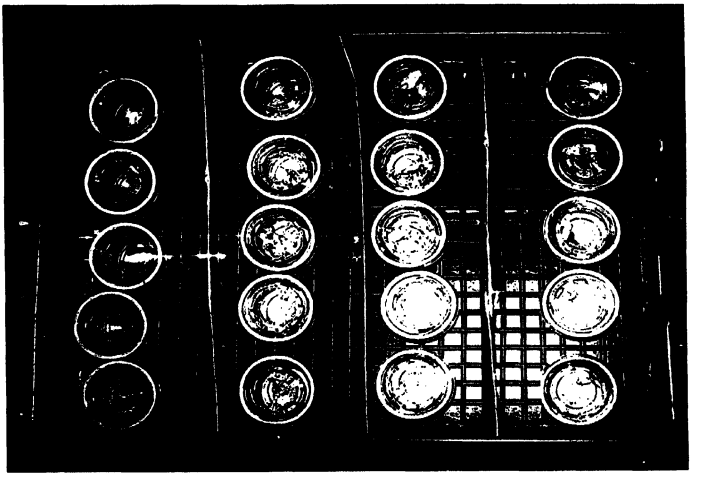


Plate 4 : Flowers of pigeonpea genotypes used for studying the growth and development of *Maruca vitrata* under laboratory conditions

twigs and the twigs then covered with muslin cloth bag. The twigs were replaced with fresh ones every day.

Observations were taken on length and weight of the larvae before releasing and take two weights of the larvae after releasing, weight of the pupae, identifying the sex of the pupae, after adult emergence take the length of the wing span and pupation percentage.

3.3 MORPHOLOGICAL AND BIOCHEMICAL CHARECTERS OF PIGEONPEA GENOTYPES

3.3.1 Morphological characters of pigeonpea genotypes

Data on certain morphological characters of listed genotypes like growth habit, time required for pod maturity, days to complete flowering, pod exposed above or below the foliage, podding habit, pod length, width and density, stem and pod wall thickness. Trichome length and density on leaves and pods were observed and correlated with resistance/susceptibility of genotypes to *Maruca vitrata*.

Genotypes 6 Replications 4

3.3.1.a Growth habit

It is observed in 6 pigeonpea genotype cultivars in each genotype 10 plants were selected. Observations were taken on Growth habit, *i.e.*, determinate or indeterminate type.

3.3.1.b Time required for pod maturity

Time required for pod maturity was taken from the date of pod initiation to harvesting of pod in 6 pigeonpea genotypes with 4 replications.

3.3.1.c Days to complete flowering

Days to complete flowering was taken from the date of flower initiation to complete flowering in 6 pigeonpea genotypes with 4 replications.

3.3.1.d Pods exposed above or below the foliage

Pods exposed above or below the foliage was observed in 6 genotypes in each genotype 10 plants were selected.

3.3.1.e Podding habit

Podding habit that is cluster or non cluster type was observed in 6 genotypes in each genotype 10 plants were selected.

3.3.1.f Length and breadth of pods

For this in 6 genotypes with 4 replications for each replication 10 uniformly developed pods were selected and measured the length and breadth with the help of graph paper.

3.3.1,g Trichome length and density

To measure trichome length and density uniformly developed leaves and pods were selected from 4 replications of 6 pigeonpea genotypes and for each replication 10 leaves and pods were selected and trichome density and length were measured in accordance with Jackai and Oghikhe (1989). The wall of the plant material was cut into bits of 9 mm^2 (3 x 3) and number of trichomes present on the epidermis of the bits were counted under a binocular microscope and similarly trichome length also was measured with the aid of binocular microscope.

Trichome length on pod was measured by gently pressing sticky transparent tape to the pod surface trichomes adhered to the sticky surface the tape was then fixed to a glass slide and trichome length was measured under a microscope with on ocular micrometer.

3.3.1.h Pod wall thickness

Handcut cross sections of pods related to 6 genotypes with 4 replications were taken and the thickness of the outer peel portion of these sections were measured with the help of verniar calipus.

3.3.1.i Stem diameter

Stem diameter was measured from 4 replications of 6 genotypes. For each replication 5 plants were selected and measured the stem diameter from middle of the plant with verniar calipus.

3.3.2 Biochemical parameters of pigeonpea genotypes in relation to susceptibility/resistance to *Maruca vitrata*

Leaves and flowers of pigeonpea genotypes were collected at 50% flowering stage and pods collected at immature stage. These leaves flowers and pods were subjected to freeze drying by using life lyser and powdered by grinder. These powdered samples were analysed for the total sugars, phenols and protein contents.

3.3.2.a Estimation of total phenols

The total phenol content in leaves, flowers and pods of pigeonpea were estimated as per the method developed by Sadasivam and Manikkam (1996).

Procedure

From each sample, 0.5 g material was weighed and added ten times volume of 80 % ethanol and centrifuged the homogenate at 10,000 rpm for 20 minutes. The supernatant was collected and residue was re-extracted with five times the volume of 80 % ethanol, then centrifuged and the supernatants were pooled and evaporated to dryness. The residue

was dissolved in a 5 ml distilled water and different aliquots 0.2 to 2.0 ml were pipetted out to test tubes, making the volume in each tube to 3 ml by adding distlled water. Then 0.5 ml of folin – ciocalteau reagent was added and after 3 minutes, 2 ml of 20 % sodium carbonate solution was added to each tube. The material was mixed thoroughly and tubes were placed in boiling water exactly for one minute. These tubes were cooled and the absorbance at 650 nm was measured against a reagent blank in spectrophotometer. The standard curve was prepared by using different concentrations of catechol. Catechol concentration were plotted on X- axis and absorbance values on Y- axis for standard curve preaparation.

Preparation of reagents

(a) Ethanol 80 % was prepared by adding 80 ml of absolute alcohol in a beaker and made upto 100 ml by using distilled water.

(b) Sodium Carbonate 20 % was prepared by adding 20 g sodium carbonate in 100 ml of distilled water.

Preparation of working standards

100 mg catechol was dissolved in 100 ml of distilled water and diluted 10 times for working standard, different concentrations from 0.1 to 1.0 ml were taken.

Calculation

From the standard curve, concentrations of total phenols in terms of mg phenols / 100 gms plant material were estimated.

Estimation of protein content

Nitrogen content of pigeonpea genotypes was determined by the modified micro- kjeldahl method suggested by Jackson (1973). The nitrogen (%) was then multiplied by the factor 6.25 (Pant and Tulsi (1969)) for obtaining the protein content.

Nitrogen estimation

The micro- kjeldalhal method (Tandon, 1999) was used for the determination of total nitrogen in pod samples of pigeonpea.

One gram of sample of pigeonpea was taken in Kjeldhal flask and 5 ml of concentrated sulphuric acid was added. After digestion, the samples were transferred to 100 ml volumetric flask and the volume was made up with distilled water and 10 ml of aliquot was fed into the micro distillating unit. The liberated ammonia trapped in one percent boric acid solution (containing a drop of methyl red) was back titrated with 0.01 N sulphuric acid. The average nitrogen present in sample was determined by using following formula.

~~titration value x 0.000014 x 100 x100~~

Nitrogen in % = titration value x 0.000014 x 100 x 100

1x10

3.3.2.c Estimation of sugars

Total sugars present in pigeonpea leaves,flowers and pods were estimated by calorimetric assay described by Sadasivam and Manikkam(1996).

Reagents

(1) 5% phenol: 5g of phenol was dissolved in 100 ml of distilled water.

(2) 96% sulphuric acid: the commercially available sulphuric acid is of 96% purity.

(3a) Standard glucose stock: 100 mg of glucose was dissolved in 100 ml of distilled water in a volumetric flask.

(3b) Glucose working stock was diluted to 100 ml in a volumetric flask.

Concentrations of glucose ranging from 20-100mg were used for developing the standard calibration curve.

(4) 2.5 HCl :- Add 21.4 ml of commercial HCl (11.7 N) to 78.6 ml of

distilled water. In a conical flask 200mg of sample was taken and 5 ml of 2.5 N HCl was added. The sample was hydrolyzed by boiling the sample on mantle heater for 3hours. The sample was cooled to room temperature and volume in the flask was made up to 100 ml with distilled water. The sample was spun down once at 5000 rpm in a centrifuge. The supernatent was collected in a conical flask and aliquots of 0.5 ml and 1.0 ml were used for estimation.

Aliquots of 0.5 and 1.0 ml were pipetted out in to different test tubes. After making up the volume to 10 ml in each tube with distilled water. 1.0 ml of 5% phenol was added followed by 5.0 ml of 96% sulphuric acid. After incubating the samples for ten minutes to room temperature, the tubes were placed on a water bath set at 25-30 degree centigrade for twenty minutes. The colour developed was read at 490 nm. The amount of total sugars present in pods was calculated from the standard glucose calibration curve established with different concentrations (20-100 mg) of glucose. The data are represented as mg / g of sample.

3.4 Evaluation of selected insecticides against *Maruca vitrata* under laboratory conditions:

Treatments 6 Replications 4

TREATMENTS	CONCENTRATIONS
Avaunt (indoxacarb)	0.5,0.75,1.0,1.25,&1.5ml/lt
Tracer (spinosad)	0.1,0.2,0.3,0.4&0.5ml/lt
Endosulfan	1.0,1.5,2.0,2.5,&3.0ml/lt
Metarhizium anisopliae	1.0,1.5,2.0,2.5,&3.0gm/lt
Bacillus thuriengeinsis	0.5,0.75,1.0,1.25,&1.5gm/lt
NSKE 5%	3%,4%,5%,6%,&7%

This experiment was conducted under laboratory conditions with the following 6 treatments *viz,* three chemical insecticides (Endosulfan, Avaunt, Tracer.), one Botanical insecticide (Azadirachtin 5%NSKE), one bacterial insecticide, (*Bacillus thuriengensis),* and one Entomopathogenic fungi *Metarhizium anisopliae.* Each treatment was tested using five concentrations and each concentration was replicated four times.

The experiment was conducted with the third instar larvae of *Maruca vitrata.* The susceptible pigeonpea genotype (ICPL 88034) twigs were collected at 50% flowering stage and they were made in the form of flower bouquets and they were in conical flask containing water. After keeping the twigs larvae in water the mouth of the conical flask was plugged with cotton and the 10 third instar larvae released on those

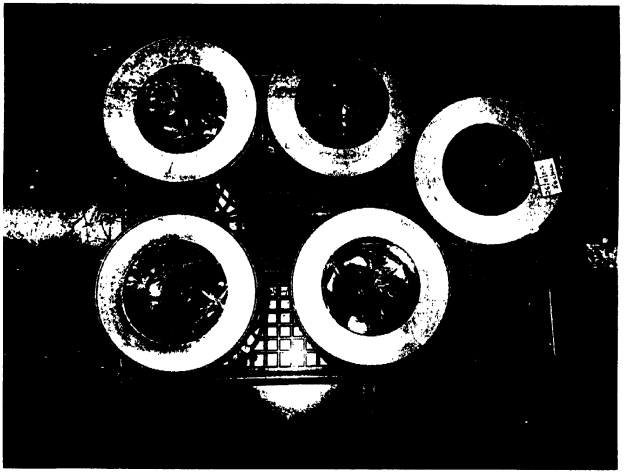


Plate 5 : Insecticidal evaluation of *Maruca vitrata* under laboratory conditions

flower bouquets then sprayed the chemicals. The larval mortality was observed at 24hrs, 48hrs, and 72hrs after treatment. And data was probit analysed using probit analysis soft ware (Chi, 1997) to find out the LC_{50} values.

CHAPTER - II

REVIEW OF LITERATURE

The spotted pod borer *Maruca vitrata* (Geyer) derives its predominate importance as a pest of tropical grain legumes from its extremely wide geographical distribution, extreme host range and its ability to infest the young growing plant tips, stems, flower buds, flowers, pods and seeds. The destructiveness at critical stages of growth *viz,* flowering and seed production constitutes a significant constraint to the productivity of grain legumes (Taylor 1967 and Raheja 1974). This pest is known by different vernacular names in different countries, Katajang moth in Indonasia (Dietz 1914), limabean pod borer in PuertoRico (Leonard and Mills 1931), legume pod borer (or) cowpea pod borer in Kenya (Okeyo-owuor and Ochieng 1981), avare pod borer and tur web worm *Maruca testulalis* (or) *Maruca vitrata* (Geyer) in India (Krishna murthy 1936, Vishakantaiah and Jagadeesh Babu 1980) respectively. In this chapter work carried out on the varietal screening, morphological and biochemical characters of pigeonpea genotypes and insecticidal evaluation against *M. vitrata* have been reviewed. Since the information pertaining to *M. vitrata* on pigeonpea varieties is limited, the literature on other pulse crops is also reviewed.

2.1 VARIETAL SCREENING FOR RESISTANCE TO *M. vitrata*

2.1.1 Field screening against *Maruca vitrata*

Screening under field conditions is very easy and cheap. If conducted in larger areas the results obtained from field screening are reliable.

Patnaik *et al.* (1986) conducted field studies on early maturing pigeonpea varieties against pod borer and reported that ICPL 81, PUSA33 and H76-208 had less infestation by *M. vitrata* (8.24 to 10.72%) compared to 15.72 to 15.91% infestation in ICPL-1 & ICPL 151 varieties.

Mali and Patil (1993) screened nine pigeonpea varieties *viz.*, T-21, BS-1, ICPC 87, ICPC 2-33, TAT-10, Sehore-68, Furus-local, Mangoan-local and Pimpalner-local under field conditions against various borers and reported that none of the varieties were completely free from damage by pod borer. However variety T-21 was found to be least infested by the gram pod borer, legume pod borer and plume moth.

Field screening of 42 entries of pigeonpea undertaken to test their reaction to pod borer complex revealed that the entry H-84-14 recorded lower grain infestation (11.41%) compared to ICPL-317 which showed highest grain infestation (57.10%) (Raut *et al.*, 1993).

Sahoo and Patnaik, (1993) reported that early maturing pigeonpea varieties suffer greater pod damage than the late maturing varieties such as CC11 and Berhampur local.

Singh *et al.* (1994) tested as many as Sixty one pigeonpea lines against *M. vitrata.* The incidence in different entries ranged from 50 – 100% except pant SDUEA-1 which showed only 2% incidence.

Singh *et al.* (1994) conducted multi locational trials with pigeonpea varieties against *M. vitrata* and reported that ICPL 4 suffered less pod borer damage followed by ICPL 151 and ICPL 86012.

Saxena *et al.* (1996) screened 271 short duration pigeonpea lines for *M. vitrata* damage and reported that determinate types suffer more damage than indeterminate types.

Anonymous (1997-98) reported that short duration pigeonpea genotypes ICPL 151 and ICPL 86012 suffer less damage by pod borer than the check entry ICPL 87.

According to Sahoo *et al.* (2002) based on the damage potential of the pod borers of the 21 field tested early cultivars of pigeonpea, AS 46, T 21, ICPL 83024, AS 36, H 82-1 and H 89-2 were found superior to others.

Durairaj and Shanower (2003) conducted an experiment involving 8 short duration pigeonpea entries against *M. vitrata* and

found that the genotypes ICPL 4, 151, 88034 and 26012 showed >15% reduction in pod damage as compared to ICPL 87 and UPAS 120.

According to Patnaik *et al.* (1986) the extent of pod and seed damage by borer complex in early maturing pigeonpea varieties, ICPL 81, PUSA 33 and H 76-208 was lesser than in ICPL 1 and ICPL 151 varieties.

2.1.2 Greenhouse screening studies

Field screening is often specific to a cropping season and therefore to particular environment conditions. Its utility is thus limited to specific periods during the year. Further more, field screening is subject to fluctuations and some times uneven pest populations which results in highly variable crop responses across locations. Resistance measured under field conditions tends to be dependent on the existing pest populations, which generally vary between locations and seasons. This can be overcome easily by making artificial infestations under laboratory and greenhouse conditions (Jackai 1991).

Sharma (1998) observed significant differences in oviposition preference of *M. vitrata* under multi choice conditions on different pigeonpea and cowpea cultivars. Maximum number of eggs were laid on ICPL 90011.

Sharma *et al.*, (1999) tested four pigeonpea genotypes, ICPL 85010, 88020, 90011 under laboratory conditions and stated that the percentage of pod damage and reduction in the number of pods were relatively lower in ICPL 90011 when compared to ICPL 88020.

Both screenhouse and field experiments showed that plant growing stage modifies the expression of cowpea resistance to *M. vitrata* larvae. Five to seven shoot stage was found to be most suitable for resistance screening in pre-flowering stage. (Dabrowski *et al.*, 1983).

Both field and screen house experiment showed that *Maruca* larvae caused significantly less damage on cowpea variety Tvu946 than on Ife Brown and Vita 1. In addition larval survival and development was negatively effected on Tvu 946 (Macfoy *et al* ., 1983).

Greenhouse experiments in choice situation have clearly shown non preference for oviposition as a component of *M. vitrata* resistance in cowpea (Macfoy *et al.*, 1983).

No choice test conducted in the screenhouse on test cowpea variety TVNu 72 showed resistance to *Maruca* similar to that determined by dual choice arena test (Jackai 1991).

2.1.3 Laboratory screening studies

Sharma (in press) reported significant differences in the consumption and utilization of pigeonpea flowers by the 3rd instar larva and pods by the fifth instar larva of *M. vitrata*.

Sharma (1998) reported that *M. vitrata* moths emerging from the larva reared on pigeonpea variety ICPL 90036-MI-2 produced maximum number of eggs, followed by those reared on ICPL 90011. Fecundity was low when the larva were reared on the pods of *Maruca* resistant cultivar MPG 537-MI-2-M5.

Sharma (1998) reported that *Maruca* larva reared on pigeonpea variety, ICPL 84023 had lower larval and pupal mass than those reared on ICPL 90036-M1-2. He stated that some of the pigeonpea genotypes were less suitable for growth and development of pod borer which may be due to nutritious or antibiotic factors. He observed that 3rd instar larvae consumed 27- 47.2 mg food on flowers and had growth rates of 114.7% on ICPL 88020 to 207.3% on ICPL 85010. Approximate digestibility (AD) was lower on ICPL 85010 than ICPL 90011. Efficiency of conversion of ingested food (ECI) into body mater was lower on ICPL 90011 compared to ICPL 85010 and ICPL 88007. The 5th instar larvae consumed 52.3 to 80.6 mg of food on pods and showed growth rates of 30.1 to 41.8%. ECI was lowest on ICPL 90011.

Macfoy *et al.* (1983) reported that survival of *Maruca* larva in cowpea was low on TVu 946 owing to its nutritional & antibiotic factors.

Okech & Saxena (1990) indicated that antibiosis was a component of resistance in Tvu 946 and VITA 5 stems and pods of cowpea varieties against *M. vitrata.*

Veldez (1989) observed only a slight effect of the hosts on survival of *M. vitrata* larva.

Suleman *et al.* (1990) studied the response of *M. vitrata* larva on three cowpea (*Vigna unguiculata*) cultivars VITA 1 (susceptible). VITA 5 (moderately resistant) and TVu 946 (resistant). Results based on the studies of food intake, utilization of ingested food, larval growth and development indicated that antibiosis was also partly involved in the resistance of TVu 946 and VITA 5 stems & pods against *M. vitrata.*

Dual choice arena test conducted by Jackai (1991) revealed that two wild cowpea relatives TVNu 72 and TVNu 73 were found to have high level of resistance to spotted pod borer *M. vitrata* based on the preference ratio and feeding index. He further stated that the susceptible cultivated cowpea line IT 845 –2246 was always prefered for feeding by the *Maruca* larvae than the *Vigna unguiculata* accessions.

2.2 MORPHOLOGICAL AND BIOCHEMICAL CHARECTERS OF PIGEONPEA GENOTYPES.

2.2.1 Morphological characters of test varieties in relation to the incidence of *M. vitrata*.

Apart form physiological and or biochemical parameters, plant resistance / susceptibility to insect pests is often effected by morphological and anatomical features.

Tall and intermediate type cultivars (non determinate type) of pigeonpeas possess fewer flowers per cluster than shorter cultivars (determinate type) and hence a disproportionately lower number of pod borer larvae per 100 flowers. Genotypes with long branching and loose flower arrangements were less susceptible to legume pod borer (Fellow *et al.*, 1977).

Lateef and Reed (1981) suggested that pigeonpea determinate types suffered greater pod borer damage than the non determinate type.

Anonymous (1975) reported that the high rate of pod growth inherent in the early flowering and maturity of Tvu 946 have been implicated in its escape of serious pod borer damage to flowers and pods in cowpea.

Cultivars with pods held within the canopy suffer significantly greater damage than the cultivars where the pods are held in the normal

position. Selection and breeding of cowpea cultivars with less dense foliage and long peduncles holding the reproductive structures above the canopy may increase resistance to *M. vitrata* (Oghiakhe *et al.*, 1991a Usua and Singh 1979)

Pods with wide angles (more than 89°) were damaged on one side but rarely on both sides. The eventual pod size and rate of pod growth appeared to be the important factors in cowpea susceptibility to the pod borer (Tayo, 1988).

Tayo (1988) reported that pod size plays an important role in the susceptibility of cowpea to *M. vitrata*. The big pods of Vita-1 provide large surface for larval infestation and sufficient nutrition for larval growth.

He further indicated that the pattern of flower and pod production as well as the development of pod and seed characteristics could be important in elucidating the physiological basis of cowpea susceptibility to the pod borer attack.

Jackai and Oghiakhe (1989) demonstrated that the trichomes and phytochemicals were responsible for resistance in wild cowpea TVNu-72 and TVNu-73 to *M. vitrata* when compared to susceptible variety IT 84 E-124. They reported that the length and angle of trichomes were more important in contributing resistance than the density of trichomes per unit area.

Laboratory studies and field experiments conducted in Nigeria on morphology, distribution and the role of trichomes in cowpea to the damage by *M. vitrata* confirmed the relevance of trichomes cover on individual cultivar to resistance. The cultivars *viz.* IT-82D-716 (susceptible), MRx2-84F (moderately resistant) and TVU-946 (resistant) showed variation in trichome length and density rather than trichome type on different plant parts (Oghiakhe *et al.*, 1992).

Oghiakhe *et al.* (1992a) studied the effect of pod angle on the resistance of cowpea to the legume pod borer *M. vitrata* and found a negative relationship between pod angle and percentage pod damage as well as the seed damage index.

Oghiakhe (1995) observed the adverse effects of pubescence in wild and cultivated cowpeas (*Vigna vexillata* and *Vigna unguiculata*) on oviposition, mobility, food consumption and utilization by the *M. vitrata.*

2.2.2 Biochemical parameters of test varieties in relation to the incidencce of *M. vitrata.*

Nutritionally important constituents of a host plant play a significant role in the feeding hebaviour of phytophagous insects (Thorstkeinson 1960). At physiological concentrations, sugars, amino acids, lipids, salts and some secondary plant substances act as phago stimulants. The combination of these components quite often produces

synergistic effects. (Beck and Hanec, 1958; Gothilfs and Beck, 1967; Doss *et al.*, 1982; Doss, 1983).

Murkute *et al.* (1993) observed that proteins, total sugars, phosphorus and potassium in the pigeonpea pods were higher in cultivars susceptible to pod borers whereas the total poly phenols as well as the activity of poly phenol-oxidase were higher in pigeonpea varieties resistant to pod borers. Thus the pigeonpea cultivars with varying degree of susceptibility to pod borer differed significantly in respect of their biochemical components.

Studies made by Sahoo and Patnaik (1993) on biochemical basis of resistance revealed that the low amino acids, proteins, sugars and high phenol contents induced resistance in the pigeonpea cultivars against borers.

Macfoy *et al.* (1983) recorded a higher concentration of sugars, amino acids, and proteins in the *Maruca* susceptible VITA 1 cowpea variety and lower concentrations in the resistant TVu 946, in addition the secondary metabolites, phenols and flavonaids and the crude fibre and dry matter contents were higher in resistant TVu 946 and thus TVu 946 may be less nutritionally suitable for *Maruca* development.

Oghiakhe *et al.* (1992) reported the variable phenol concentrations of cowpea cultivar in different parts of same growth stage. The differences in phenol concentrations among cultivars at

different growth stages revealed that phenol does not play any significant role in cowpea resistance to *M. vitrata.*

Sugar contents in the pod walls of cowpea cultivar TVNu-72 was greater than in IT 82D-716 and phenol content was lower in the pod wall of TVNu 72, but the reverse was true for fresh and dry seeds. Neither sugars nor phenols seems to be involved in the resistance of TVNu 72 to *M. vitrata.* (Oghiakhe *et al.*, 1993).

Chabra *et al.* (1984) reported that mungbean cultivars LU-15, LU-173, LU-190, LU-196, LU-330, LU-397, LU-426 and LU-434 were resistant to pod borers such as *Lampides boeticus* (L), *M. vitrata* and *Helicoverpa armigera.* These cultivars recorded higher reducing and non reducing sugars, total phenols, free amino acids in leaves. These components were reported to serve as defensive mechanism against the pod borer complex as compared to susceptible cultivars which had significantly lower concentrations of these components.

2.3 EVALUATION OF INSECTICIDES AGAINST *M.VITRATA*

2.3.1 Evaluation of Novel insecticides against *M. vitrata*

A number of novel insecticides have been recently registered for insect control in agriculture. A major advantage of these new products is that they act on insect biological process. They also posses greater

selectivity to target specific species. So they are less likely to harm natural enemies when compared with the other chemicals.

Indoxacarb is relatively a new molecule of oxadiazine group of insecticides. Since the literature pertaining to the efficacy of indoxacarb and spinosad against *M. vitrata* on pigeonpea is meager, its efficacy against other lepedopterous pests of other crops was also reviewed. The information pertaining to the efficacy of novel inseciticides *viz.*, indoxacrab and spinosad used in the present study was reviewed.

Suhas *et al.* (1999) reported that application of indoxacarb 14.5 SL @ 50 g a.i.ha^{-1} was very effective in bringing down the pod damage by *H. armigera* in pigeonpea to 23.1 per cent as against 47.5 per cent in untreated check.

Bheemanna and Patil (1999) determined the efficacy of indoxacarb on cotton insect pests and concluded that indoxacarb @ 75 g a.i. ha^{-1} was very effective in controlling *H. armigera.*

Naveed *et al.* (1999) reported that indoxacarb @ 65 g a.i. ha^{-1} resulted in 85 percent mortality of *H. armigera* larvae at fifth day after treatment in cotton. Three new insecticides, betacyfluthrin, spinosad and indoxacarb were equally promising for the control of pink bollworm on cotton (Gopalaswamy *et al.*, 2000).

Indoxacarb @ 1 ml l^{-1} was highly effective in controlling *H. armigera* in cotton by giving 100 per cent mortality and was on par with spinosad, thiodicarb and chlorpyriphos (Rao *et al.*, 2001).

The new molecules, spinosad and indoxacarb exhibited moderate ovicidal activity against *H. armigera* on cotton at recommended doses and showed improved efficacy at higher doses (Rao *et.al.*, 2001).

Babu (2002) observed the highest efficacy of indoxacarb @ 0.0145 % among the various treatments against *H. armigera* in groundnut by recording 73.76 per cent reduction of pest population at three days after spraying.

Papa *et al.* (1999) reported that application of indoxacarb alone @ 400 ml ha^{-1} resulted in 83 per cent reduction of *S. litura* in cotton where as indoxacarb in combination with lufenuron @ 400 ml ha^{-1} gave 92 per cent control.

Khalid Ahmed *et al.* (2001) recorded 86.66 per cent ovicidal effect against *S. litura* eggs with indoxacarb @ 0.024 % followed by spinosad @ 0.015 % which recorded 73.33 per cent ovicidal action.

Bharpoda *et al.* (2003) evaluated the effectiveness of indoxacarb (Avaunt) 15% SC in comparision to some of the conventional synthetic insecticides, *viz,* cypermethrin, chlorpyriphos and acephate alone and in combination with indoxacarb against insect pests of ' H6' upland cotton.

Indoxacarb sprayed on 'H6' cotton @75g a.i/ha showed significant superiority to rest of insecticides in terms of giving protection to buds and bolls of cotton crop against boll worms.

Balaji (2002) reported the lowest shoot infestation (10.76) by *Leucinodes orbonalis* Guenee when indoxacarb was sprayed @ 0.0145 % on brinjal.

Spinosad is a natural insecticide which has spinosyn as an active principle. It is a mixture of spinosyn A and spinosyn D produced as a fermentation by product from soil actinomycetes, *Saccharopolyspora spinosa* (Dey and Somchoudhury, 2001). Spinosad 45 SC acts as both contact and stomach poision and has low mammalian toxicity and is selective against lepidopteran pests (Adan *et al.*, 1996).

Dey and Somchoudhury (2001) reported that spinosad 48 SC (spinosyn A+D) was effective in controlling the three important pests of cabbage *viz, Spodoptera litturalis, Plutella xylostella*, and *Hellula undalis* @15.25 g a.i /ha. Spinosad 48 SC @ 0.4 ml was very effective against early instar larvae of *H. armigera* in cotton and recorded 100per cent mortality at three days after treatment (Rao *et al.*, 2001).

Dandale *et al.* (2000) concluded that spinsoşad 48 SC at 75 and 50 g a.i ha^{-1} was effective in controlling the infestation of *H. armigera* in green fruiting bodies of cotton plant at 14 days after treatment.

Khalid Ahmed *et al.* (2001) reported that spinosad has recorded 71.11 per cent mortality against *S. litura* in chillies.

Patil *et al.* (1999) reported that the combination treatment of spinosad 48 SC + chlorpyriphos 20 EC @ 500 g a i.ha^{-1} and spinosad 48 SC alone at 100 g ai. ha^{-1} were superior in reducing the insect damage in cotton by recording 6.17 per cent and 8.5 per cent bollworms, respectively as against 41.12 per cent in control and recorded the highest yields.

Babu (2002) reported 44.07 per cent and 44.87 per cent reduction of *H. armigera* and *M. vitrata* larvae respectively when spinosad 48 SC @ 0.0144% was applied on groundnut.

The new insecticide spinosad (26.33%) was equally promising for the control of pink boll worm so as the case with the commonly used quinolphos (26.35) and popular pyrethriod cypermethrin (27.18%) (Gopalaswamy *et al.*, 2000).

Spinosad 2.5 SC @ 15g a.i/ha was effective in protecting cabbage against *Plutella xylostella* and recorded lesser population of larvae per plant (0.73) as against 6.4 in control, at seven days after treatment (Walunj *et al.*, 2001).

Spinosad 45 SC at higher dosages (90 g a.i. / ha) recorded significantly lower pod damage and higher grain yield. However even at

lower doses (56 g a.i/ha) recorded lower pod damage and higher grain yield compared to endosulfan 35 EC, 700g a.i/ha (SiddeGowda *et al.*, 2003).

Vadodaria *et al.* (2001) stated that spinosad 48SC @75g ai. /ha was very effective in controlling boll worms of cotton by recording lower larval population of 1.4 larvae per 5 plants and higher seed yield of 1844 Kg /ha.

2.3.2 Evaluation of conventional insecticides against *M.vitrata*

The conventional insecticides are among the most popular chemical control agents because they are readily available, rapid acting and highly reliable. A single application may control several different pest species and usually forms a persistent residue that continues to kill insects for hours or even days after application. Conventional insecticides are found highly effective against pod borers (Balasubramanian *et al.*, 1977). The literature pertaining to the mostly commonly used conventional insecticid tested in the present study *i.e.*, endosulfan was reviewed.

Endosulfan is a cyclodiene compound having both contact and stomach poison with a slight fumigant action (David and Kumaraswamy, 1988).

Sundarababu and Rajasekaran (1984) reported that spraying of triazophos (0.07%), endosulfan (0.07%) and monocrotophos (0.04%) gave effective control of pod borers on pigeonpea. Samalo and Patnaik (1986) reported that among the six insecticides tested against pigeonpea pod borers, monocrotophos and endosulfan (0.5 Kg ai ha^{-1}) were most effective.

Ramasubramanian and Sundarababu (1991) reported that among the insecticides tested on beans spraying of endosulfan (0.518 kg ai. /h) and NSKE 5% were effective in reducing the larval population of *M. vitrata.*

Sontakke and Mishra (1991) reported that endosulfan @ 400 g ai. ha^{-1} was as effective as synthetic pyrethoids in the management of pod borer complex on pigeonpea.

Choudhary and Sachan (1997) reported that spraying endosulfan (0.07%) at flowering, pod formation and pod maturation stages of pigeonpea gave effective control of pod borer complex and resulted in higher yields. The highest cost benefit ratio was also obtained with one spray of quinolphos and two sprays of endosulfan (Singh, 1997).

Girhepuje *et al.* (1997) reported that endosulfan @ 0.07% showed 68.62 and 61.11 percent reduction of pod borer and podfly on pigeonpea, respectively. Effective control of pod borers in pigeonpea was obtained with endosulfan 35 EC @ 0.05% which recorded 0.69 pod

borers plant^{-1} as against 7.63 in untreated control at three days after treatment (Sahoo and Senapathi, 2000).

Akhauri and Yadav (1999) reported that endosulfan 0.07% gave better performance compared to untreated check in reducing the pod borer damage in pigeonpea.

Das Mohapatra and Srivastava (2002) reported that endosulfan @ 360 g a.i. ha^{-1} was the best treatment in controlling pigeonpea pod borer, *M.vitrata* as it recorded the least number of larvae of 0.9 when compared to 5.1 in untreated control.

The bioefficacy of various treatments showed that endosulfan 0.07% had the least larval population after three days of spraying followed by NSKE 5% + endosulfan 0.035% (Ramteke *et al.*, 2002).

2.3.3 Evaluation of biopesticides against *M. vitrata*

Biopesticides make use of naturally occurring pest killers such as plant products and microbial pesticides to reduce the development of resistance and the adverse effects of toxic chemicals on non-target organisms and pollution to the environment. Entomopathogens can be mass produced and applied in much the same way as synthetic insecticides.

Metarhizium anisopliae (Metsch) Sorokin is a green muscardine soil inhabiting fungus and is a potent microbial insecticide. Mass

production of *M. anisopliae* is easy and cheap and does not require high input technology (Prior,1988). The fungus can be formulated and applied in a variety of ways and therefore could provide a novel alternative to the use of chemical insecticides for the control of the pests. The ovicidal activity of 8 isolates of entomopathogenic hypomycetes were evaluated in the laboratory against *M. vitrata* and *Clavigrella tomentosicollis* @ $1x10^8$ conidia/ml. Four isolates (*Beaveria bassiana* CPD 3 & 10 and *Metarhizium anisopliae* CPD 5&12) were found to be highly pathogenic to eggs of *M. vitrata* and recorded 89-100% mortality at a given concentration. These isolates also caused high larval and nymphal mortalities of 94 and 100% in *M. vitrata* and *C. tomentosicollis* respectively (Ekesi *et al.*, 2002).

Gopalakrishnan and Narayanan (1988) conducted pathogenicity tests by spraying the aqueous spore suspension of the *M. anisopliae* fungus (1.8×10^9 spores per ml) against all the 5 different instars of *H. armigera.* Results showed that the fungus was highly virulent inflicting 100% mortality to all the instars except in the case of 5^{th} instar where the mortality was 80% with an incubation period ranging from 2 to 5 days.

M. anisopliae has been found to be pathogenic to larval instars, pre pupae and pupae of *H. armigera* when it was tested at a concentration of 1.8×10^9 conidia/ml by inflicting 80-100% mortality.

None of the adults and eggs treated with conidial suspension showed any mortality (Goplakrishnan and Narayanan, 1989).

The pathogenicity studies of *B. bassiana* and *M. anisopliae* (5 x 10^6 and 5 x 10^7 conidia / ml) to the eggs and pupae of *S. litura, Spilosoma obliqua* and *H. armigera* revealed that an increase in concentration by 10 folds increased the mortality of eggs from 9 to 20% only.

Bacillus thuringiensis (B.t) is an aerobic, gram positive bacteria which produces a number of toxins, the most distinictive of which is δ-endotoxin formed during sporulation (Whiteley and Schnepf, 1986).

Taylor (1969) explored the possibility of integrated approach for the suppression of pest complex of cowpea. He stated that *Bt* (0.5%) was highly effective against *M. vitrata.*

Manjula and Padmavathamma (1996) concluded that *Bt* @ 1x 10^7 ml^{-1} + monocroptophos @ 0.025% were effective against *M.testulalis* on pigeonpea. Durairaj (1999) reported that two strains of *Bt* (*B.t* k-I and *B.t* k-II), NPV and combination of endosulfan and NPV were highly effective in reducing the pod borer damage in pigeonpea.

Das Mohapatra and Srivastava (2002) reported that *B.t* (Biobit) @ 1000 g a.i ha^{-1} was effective in controlling pigeonpea pod borer *M.vitrata.*

Purohit and Deshpandey (1991) evaluated the efficacy of *Bt* Kurstaki against third instar larvae of *H. armigera* and reported the LC_{50} value as 0.179.

Shankar *et al.* (1992) evaluated *Bt* (Biobit WP) against pigeonpea pod borer and reported that Biobit WP @ 1.5 Kg ai. ha^{-1} was effective in controlling *H. armigera* with a mean per cent pod damage of 3.00 as against 24.66 per cent in untreated control.

Halt (*B.t*) @ 1000 g ha^{-1} was found to be effective in controlling the lepidopterous pod borer complex on pigeonpea and recorded only 7.74% pod damage (Pawar and Gunjal, 1995).

Karel and Schoonhoven (1996) reported that two applications of *B.t* during post flowering growth stage of bean plants controlled the larvae of pod borers on pigeonpea as effectively as two applications of lindane or carbaryl.

Mohammed and Rao (1999) concluded that *B.t* @ 0.1% was effective in controlling larvae of *H. armigera* in pigeonpea which recorded 8.2 per cent pod damage as against 14.7 in untreated control. The treatment also recorded the highest yield of 1040 kg/ha as compared to 910 kg/ha in untreated control.

Gaikwad *et al.* (1998) reported 80 per cent mortality of second instar larvae of *H. armigera* with Delfin 1000 ml l^{-1}.

Pawar *et al.* (1999) reported that spraying with Halt (Wock Biological-01) was on par with fenvalerate 100 ml ha^{-1} when applied at 50 per cent flowering stage at fortnightly intervals in reducing the pod damage and increasing grain yield of chickpea.

Venkatasubramanian and David (1999) reported that *Bt* var kurstaki, *gallaria* and *aizawai* each at 0.1% in combination with botanicals *viz,* neem seed oil (15%) and palmarosa plant oil (0.5%) were significantly superior against tobacco cut worm *S. litura* and gram pod borer *H. armigera.*

Minja *et al.* (2000) reported that NSKE and *Bt* were not as effective as the synthetic insecticides in reducing pest numbers and pigeonpea seed losses.

Narendra reddy *et al.* (2001) reported that Dipel *(Bt)* with deltamethrin (0.004% (or) 0.002%) was most effective in reducing the damage due to pod borers in pigeonpea.

Bhuvaneswari and Balagurunathan (2003) reported that the results obtained with *B.t* @ 1000 g a.i ha^{-1} was on par with endosulfan @ 0.07% in controlling *H. armigera* in pigeonpea.

Azadirachtin, a tetraterpinoid was known for its potent antifeedent property. The compound was first isolated from neem tree *Azadirachta indica* Juss by Butterworth and Morgan (1968).

Azadirachtin is structurally similar to the insect moulting hormone ecdysone and interacts with the corpus cardiacum there by blocking the activity of moulting hormone. As such the compound acts as an insect growth regulator suppressing fecundity, moulting, pupation and adult formation (Schmutterer, 1995).

Ramasubramanian and Sundarababu (1991) reported that among the insecticides tested, spraying of endosulfan (0.518 kg a.i/h) and NSKE 5% were on par in reducing the larval population of *M. vitrata* on lab lab.

Rao and Rao (1990) reported that Repelin @ 1.5 % was found effective against pod borer, *H. armigera* when applied at 8 days interval synchronizing with flower initiation and 50 per cent flowering and pod maturity on pigeonpea.

Two applications of NSKE @ 5% concentration was the most effective treatment in minimizing pod damage and maximum larval reduction of *H. armigera* in pigeonpea (Sarode *et al.*, 1995).

Durairaj and Venugopal (1995) reported that neem seed kernel extract (NSKE) 5% was effective against podfly and lepidopteran borers in pigeonpea.

Latif *et al.* (1996) observed that nimbicidine (0.3%) was next to monocrotophos 36 SL (0.04%) when sprayed thrice at 12 days interval

in giving the highest protection and yielded maximum against major insect pests of pigeonpea.

Sadwarte and Sarode (1997) reported that the application of NSKE 5% + half recommended dose of insecticides resulted maximum larval reduction of *H. armigera*, *Exelastis atomosa* and minimum larval infestation of *M.obtusa* on pigeonpea, whereas the application of NSKE alone was not effective against pod borer complex of pigeonpea. The lowest damage and the highest grain yield was observed using NSKE at 5% + dimethoate 0.15%.

Girhepuje *et al.* (1997) reported that as compared to other treatments, neem seed kernel extract (5%) was found to be the least effective chemical against pod borer complex in pigeonpea and recorded minimum grain yield.

Akhauri and Yadav (1999) reported that neem oil, mahua oil and NSKE at 2.0 and 5.0 per cent, respectively gave better performance compared to untreated check in reducing the pod borer damage in pigeonpea and resulted in higher grain yield.

Sahoo and Senapathi (2000) reported that NSKE 5% significantly reduced the pod borer larvae of pigeonpea per plant (1.95) at 3 days after treatment. Das Mohapatra and Srivastava (2002) observed a significant reduction of larvae of *M. vitrata* on pigeonpea when NSKE was sprayed @ 5% concentration.

Sandnya *et al.* (2003) reported that NSKE proved to be the most effective and significantly superior to the rest of the other treatments in maintaining the lower level of larval population of *H. armigera* in chickpea.

According to Mane (1968) 3% Neem seed kernal suspension was reported to be an effective antifeedant against all the five larval instars of *S. litura.*

CHAPTER -III

MATERIALS AND METHODS

Studies on screening of some promising pigeonpea genotypes against *Maruca vitrata* (Geyer) were conducted under field, greenhouse and laboratory conditions and the efficacy of certain new insecticides were also evaluated against the *M. vitrata* under labaratory conditions at International Crops Research Institute for the Semi Arid Tropics (ICRISAT) Asia center, Patancheru, Andhra Pradesh during 2004-2005 crop season. The materials used and methods employed in the present studies are presented here under.

3.1 Screening of pigeonpea genotypes against *M.vitrata*

3.1.1 Experimental material

The present study was conducted with six short duration pigeonpea genotypes. The details of the test genotypes were given in (Table 1).

For varietal screening studies six pigeonpea genotypes i.e. ICPL 98001, ICPL 98002, ICPL 98003, ICPL 98008, ICPL 98012 and ICPL 88034, were selected and screened under field conditions as well as under artificial infestation in the greenhouse and laboratory for resistance to *M. vitrata* during kharif season from june 2005 to October

2005 at ICRISAT, Asia center. The various screening techniques followed are described below ..

3.1.2 Screening of pigeonpea genotypes for resistance to *M.vitrata* under field conditions

The present investigation was conducted at ICRISAT, Patancheru, India. The latitude and longitude of the experimental plot are 17° 27' S and 78° 28' N, respectively and altitude is 545 m above sea level.

Six pigeonpea genotypes *i.e.*, ICPL 98001, ICPL 98002, ICPL 98003, ICPL 98008, ICPL 98012 and ICPL 88034, were planted on 28th june 2005 in a randomized block design (Fig. 1) in red precision 7B (South) fields of ICRISAT farm. Each cultivar was sown in two rows of each measuring 3m length with a spacing of 60x10 cm with a plot size of 1.8 m^2. Four replications were maintained for each treatment. Recommended agronomic practices were followed to raise the crop except the plant protection measures. Basal fertilizer N : P : K was applied at the rate of 100 : 60 : 40 in rows before sowing. Top dressing with urea @ 80 kg/ha was given at one month after crop emergence. Weeding was carried out as and when needed (Plate 1). Observations on *Maruca* infestation was recorded during peak pod infestation when some of the lines were completely damaged by *Maruca* (Bindra and Jakhmola (1967)) and Sahoo and Senapati (2000). The pod

damage was recorded by selecting ten plants from each replication. From each plant five peduncles were randomly selected and pods on the selected peduncles were examined for *M.vitrata* injury. The number of injured pods on each peduncle was then expressed as percentage. Based on the per cent pod damage the damage score for each genotype was calculated and were given the resistance rating 1-5 as suggested by Jackai (1982).

Pod damage(%)	Score	Resistancerating
0 – 20	1	Highly resistant
21 – 40	2	Moderately resistant
41 – 60	3	Intermediate
61 – 80	4	Susceptible
81 – 100	5	Highly susceptible

3.1.3 Greenhouse and laboratory studies for evaluating pigeonpea genotypes against *M. vitrata*

Artificial infestation of the test plants under greenhouse and laboratory conditions requires large population of laboratory reared insects. In the present study the technique of mass rearing on artificial diet developed by Ochieng *et al.* (1981) was used for rearing *M. vitrata*.

3.1.3.1 Mass rearing of *M.vitrata* on artificial diet

Field collected fifth instar larvae of *M.vitrata* were utilized for maintaining the mass culture. The larvae were reared in clean and sterilized glass troughs of 13 x 30 cm on artificial diet. Pupae obtained were kept in a plastic container with cotton pads for adult emergence. Newly emerged adults (ten males and ten females) were released into oviposition cages of 60 x 30 x 90 cm size and were fed with 10 % sugar solution soaked in cotton swabs. Fresh tender twigs of pigeonpea genotype (ICPL 88034) bearing the inflorescence were placed in conical flasks filled with water and the mouths were plugged with cotton. The flasks bearing the inflorescence were kept in cages for egg laying. The twigs were changed daily and the flowers, flower buds and tender leaves were examined for the presence of egg masses. The collected egg masses were placed on moist (Whatmann no. 41) filter paper kept in Petri plates. After hatching, the larvae were maintained on artificial diet. The food was regularly replenished with the freshly prepared diet.

3.1.3.2 Method of preparation of artificial diet

The details of required ingredients for preparing 1 litre of diet are as follows.

Water (for blending)	500 ml
Chickpea flour	100 g

Pigeonpea leaf powder	12.5 g
Ascorbic acid	6.25 g
Methyl para hydroxy benzoate	1.58 g
Sorbic acid	0.96 g
Sugar	15 g
Cholin chloride (15 %)	7.4 ml
KOH (4 M)	5.5 gm
Wheat germ	31.8 gm
Wesson salt mix	10.6 gm
Acetic acid (25%)	12.5 ml
Formaldehyde (10%)	6.5 ml
Aureomycin (5% a.i)	2.75 g
Vitamin solution	7.50 ml
Water (for blending Agar)	500 ml
Agar	14.80 g

Ingredients such as chickpea flour, pigeonpea leaf powder, ascorbic acid, methyl parahydroxy benzoate, sorbic acid, sugar, cholin

chloride (5%), KOH, wheat germ, wesson salt mix, acetic acid, formaldehyde, aureomycin and vitamin solution were added to 500 ml of water and blended for 2 to 3 minutes. Another 500 ml water was boiled and Agar was added to it with thorough mixing. After little cooling it was added to earlier mixture in the blender and again blended for 2-3 minutes. The cooled diet mixture was poured in the trays and was used for rearing *M. vitrata* larvae.

3.1.3.3 Greenhouse screening

Cage technique developed by Sharma (in press) was used to screen pigeonpea genotypes for resistance to the pod borer *M.vitrata* under greenhouse conditions by subjecting the genotypes to uniform insect pressure at 50% flowering stage of the crop (Plate 2). The six pigeonpea genotypes were planted in separate pots at the rate of one plant per pot with 4 replications of each treatment. Each replication of the treatment was infested with 10 first instar larvae at 50% flowering stage and covered with a muslin cloth (Plate 3). Infested plants were evaluated for insect damage at 15 days after larval inoculation.

Observations were taken on the larval weight gain, larval mortality, number of healthy and damaged pods, per cent pod damage and grain yield. The observations were subjected to anova way CRD analysis.

3.1.3.4 Laboratory screening

Flowers were considered to be most suitable for studying the larval development under laboratory conditions (Suleman *et al.*, 1990). Hence, laboratory studies were conducted with the flowers of six pigeonpea genotypes against *M. vitrata*. Flowers of each genotype were collected from unsprayed field, weighed and kept in plastic cups separately(Plate 4). Ten first instar larvae were released on flowers kept in separate cups. Each treatment was replicated four times. The flowers in the cup were changed daily with freshly weighed flowers till the larval period was completed.

Observations were taken on mass of food consumed by the larvae, mass of frass excreted, larval weight gain, growth rate (%), weight of the pupae and pupation(%). By utilizing the above data, efficiency of conversion of ingested food into body matter (ECI), efficiency of conversion of digested food into body matter (ECD), approximate digestability (AD) and consumption index (CI) of *M. vitrata* larvae were calculated separately for each genotype by using the following formulas.

$$ECI = \frac{\text{Weight gained by larvae}}{\text{Weight of food ingested}} \times 100$$

$$ECD = \frac{\text{Weight gained by larvae}}{\text{Weight of food ingested- Weight of faeces}} \times 100$$

$$CI = \frac{F}{TA}$$

F = Weight of food eaten (mg)

T = Duration of feeding period (days)

A = Mean dry weight of insect during feeding period

$$AD = \frac{\text{Weight of food ingested – weight of faeces}}{\text{Weight of food ingested}} \times 100$$

3.2 MORPHOLOGICAL AND BIOCHEMICAL CHARECTERS OF PIGEONPEA GENOTYPES

3.2.1 Morphological characters of pigeonpea genotypes

Data on certain morphological characters of test genotypes like growth habit, time required for pod maturity, days to complete flowering, pods exposed above or below the foliage, podding habit, pod length, width, pod wall thickness, trichome length and density of leaves and pods were observed and correlated with incidence of *M.vitrata.*

3.2.1.1 Growth habit

Growth habit of the six pigeonpea genotypes *i.e.*, determinate or in determinate type was recorded.

3.2.1.3 Days to complete flowering

Days to complete flowering was taken from the date of flower initiation to completion of flowering in six pigeonpea genotypes, each of which were replicated four times.

3.2.1.2 Time required for pod maturity

Time required for pod maturity was calculated by taking the observations from the date of pod initiation to harvesting of pods in six pigeonpea genotypes consisting of four replications of each treatment.

3.2.1.4 Pods exposed above or below the foliage

Pods exposed above or below the foliage was recorded in all the genotypes. In each genotype ten plants were observed.

3.2.1.5 Podding habit

Podding habit of each genotype i.e. cluster or non cluster type was observed in each genotype.

3.2.1.6 Length and breadth of pods

The length and breadth of the pods of each genotype were observed with the help of graph paper. Four replications were maintained for each genotype and in each replication ten pods were observed.

3.2.1.7 Trichome length and density

For measuring the trichome length and density in six pigeonpea genotypes,, uniformly developed leaves and pods were selected from four replications of six pigeonpea genotypes and for each replication ten leaves and pods were selected and trichome density and length were measured in accordance with Jackai and Oghiakhe (1989). For measuring the trichome density, leaves and pod wall were cut into bits of 9 mm^2 (3 x 3) and number of trichomes present on the epidermis of the bits (leaves and pods) were counted under a binocular microscope (10x100x) and similarly trichome length on leaves was also measured with the aid of binocular microscope.

Trichome length on pods was measured by gently pressing the sticky transparent tape to the pod surface and the trichomes adhered to the sticky surface were then fixed to a glass slide and trichome length was measured under binocular microscope with the help of ocular micrometer.

3.2.1.8 Pod wall thickness

Hand cut cross sections of pods of six pigeonpea genotypes were taken and the thickness of the outer peel portion of four sections of each treatment were measured with the help of Vernier calipus.

3.2.2 Biochemical parameters of pigeonpea genotypes

The biochemical constituents *i.e.*, total sugars, total phenols and protein content were estimated in leaves flowers and young pods of six pigeonpea genotypes. For estimation, the leaves and flowers at 50% flowering stage and young pods were collected and subjected to freeze drying by using freeze dryer and powdered with the help of grinder. The powdered samples were analysed by using the following procedures.

3.2.2.1 Estimation of total phenols

The total phenols present in leaves, flowers and pods of six pigeonpea genotypes were estimated as per the method developed by Sadasivam and Manickam (1996). From each sample, 0.5 g material was weighed and was added with ten times volume of 80 % ethanol and the homogenate was centrifuged at 10,000 rpm for 20 minutes. The supernatant was collected and residue was re-extracted with five times the volume of 80 % ethanol, then centrifuged and the supernatants were pooled and evaporated to dryness. The residue was then dissolved in 5 ml distilled water and different aliquots ranging from 0.2 to 2.0 ml

were pipetted out in to the test tubes and the volume in each tube was made upto 3 ml by adding distilled water. To this extract 0.5 ml of folin – ciocalteau reagent was added and after 3 minutes, 2 ml of 20 % sodium carbonate solution was added to each tube. The material was mixed thoroughly and tubes were placed in boiling water exactly for one minute. The tubes were then cooled and the absorbance was measured at 650nm against a reagent blank in spectrophotometer. The standard curve was prepared by plotting the catechol concentrations on X- axis and absorbance values on Y- axis.

3.2.2.1.1Preparation of reagents

(a) Ethanol 80 % was prepared by adding 80 ml of absolute alcohol in a beaker and made upto 100 ml by using distilled water.

(b) Sodium Carbonate 20 % was prepared by adding 20 g sodium carbonate in 100 ml of distilled water.

3.2.2.1.2 Preparation of working standards

The working standards were prepared by dissolving 100 mg catechol was dissolved in 100 ml of distilled water and diluted to 10 times From the working standards, different concentrations ranging from 0.1 to 1.0 ml were prepared.

3.2.2.1.3 Calculation

From the standard curve, concentrations of total phenols in terms of mg phenols / 100 gms plant material was estimated and converted to per cent.

3.2.2.2 Estimation of protein content

Nitrogen content of pigeonpea genotypes in leaves, flowers and pod samples of six pigeonpea genotypes was determined by the modified micro- kjeldahl method suggested by Jackson (1967). The nitrogen content (%) was then multiplied by the factor 6.25 (Pant and Tulsi (1969) for obtaining the protein content.

3.2.2.2.1 Nitrogen estimation:

One gram sample of pigeonpea was taken in Kjeldhal flask and 5 ml of concentrated sulphuric acid was added. After digestion, the samples were transferred to 100 ml volumetric flask and the volume was made up with distilled water and 10 ml of aliquot was fed into the micro distillating unit. The liberated ammonia trapped in one per cent boric acid solution (containing a drop of methyl red) was back titrated with 0.01 N sulphuric acid. The average nitrogen present in sample was determined by using the following formula.

$$\text{Nitrogen \%} = \frac{\text{Titration value} \times 0.000014 \times 100}{1 \times 10} \times 100$$

3.2.2.3 Estimation of sugars

Total sugars present in pigeonpea leaves, flowers and pods were estimated by calorimetric assay described by Sadasivam and Manikkam (1996).

3.2.2.3.1 Reagents

(1) 5% phenol : 5 g of phenol was dissolved in 100 ml of distilled water

(2) 96% sulphuric acid: The commercially available sulphuric acid is of 96% purity.

(3a) Standard glucose stock: 100 mg of glucose was dissolved in 100 ml of distilled water in a volumetric flask

(3b) Glucose working stock was diluted to 100 ml in a volumetric flask.Concentrations of glucose ranging from 20-100mg were used for developing the standard calibration curve.

(4) 2.5 N HCL: Add 21.4 ml of commercial HCL (11.7 N) to 78.6 ml of distilled water.

200 mg of sample was taken in a conical flask and 5 ml of 2.5 N HCL was added and hydrolyzed by boiling the sample on mantle heater

for 3hours. The sample was cooled to room temperature and the volume was made up to 100 ml by adding distilled water and supernatent was collected and aliquots of 0.5 ml and 1.0 ml were used for estimation. Aliquots of 0.5 and 1.0 ml were pipetted out in to different test tubes. After making up the volume to 10 ml in each tube with distilled water, 1.0 ml of 5% phenol was added followed by 5.0 ml of 96% sulphuric acid. After incubating the samples for ten minutes to room temperature, the tubes were placed on a water bath set at 25-30^{0}C for twenty minutes. The colour developed was read at 490 nm. The amount of total sugars present in samples was calculated from the standard glucose calibration curve established with different concentrations (20-100 mg) of glucose. The data were represented as per cent

3.2.2.4 Statistical analysis

Morphological and biochemical parameters of test genotypes were analysed by using CRD and these parameters were correlated with percentage of pod damage under field, green house and laboratory screening data. Correlation coefficients and simple linear regression analysis was carried out to develop simple regression models.

3.3 EVALUATION OF SELECTED INSECTICIDES AGAINST *MARUCA VITRATA* UNDER LABORATORY CONDITIONS:

Table 1: Details of insecticides used in the present study:

TREATMENTS	CONCENTRATIONS
Indoxacarb	0.5,0.75,1.0,1.25 & 1.5ml/l
Spinosad	0.1,0.2,0.3,0.4 & 0.5ml/l
Endosulfan	1.0,1.5,2.0,2.5 & 3.0ml/l
Metarhizium anisopliae	1.0,1.5,2.0,2.5 & 3.0gm/l
Bacillus thuringiensis	0.5,0.75,1.0,1.25 &1.5gm/l
Neem fruit extract 5%(NFE)	3%, 4%, 5%, 6% & 7%
Control	--

The experiment was conducted under laboratory conditions with seven treatments consisting of two novel insecticides (indoxacarb, spinosad.), one conventional insecticide (endosulfan) one botanical insecticide (Azadirachtin 5%NFE), one bacterial insecticide, (*Bacillus thuringiensis),* one entomopathogenic fungi (*Metarhizium anisopliae)* and control. Each treatment was tested at five concentrations (one being the recommended dose, two concentrations below the recommended dose and two concentrations above the recommended dose) and each concentration was replicated four times.

The experiment was conducted with the laboratory reared third instar larvae of *M. vitrata*. The unsprayed pigeonpea genotype (ICPL 88034) twigs were collected at 50% flowering stage from the field and they were made in the form of flower bouquets and were kept in conical flask containing water (Plate 5). After keeping the twigs in water, the mouth of the conical flask was plugged with cotton and ten third instar larvae were released on each flower bouquets and then sprayed with the chemicals by using small Ganesh sprayer. The flower bouquets sprayed with water was kept as control. The larval mortality was observed at 24, 48 and 72 hrs after treatment and the per cent mortality was calculated and subjected to Anova way CRD.

CHAPTER – IV

RESULTS

4.1 SCREENING OF PIGEONPEA GENOTYPES AGAINST *Maruca vitrata*

In the present study selected pigeonpea genotypes were screened for their resistance / susceptibility to *M. vitrata* under field, greenhouse and laboratory conditions and the results are presented here under.

4.1.1 Screening of pigeonpea genotypes in the field

Six pigeonpea genotypes tested for their reaction to the infestation of spotted pod borer (*M. vitrata*) showed a significant variation in respect of per cent pod damage (Table 3).

Among the six genotypes, ICPL 88034 recorded significantly highest pod damage (68.00%) followed by ICPL 98002 (51.00 %) and ICPL 98001 (49.25 %) which were on par with each other. The pod damage recorded in ICPL 98012 was 24.50 per cent. Lowest pod damage was recorded on ICPL 98003 (5.80 %) and ICPL 98008 (6.77 %).

Table-3 : Field screening of six short duration pigeonpea genotypes against spotted pod borer *Maruca vitrata* during *Kharif* season 2004 – 2005 at ICRISAT Asia Center (IAC), India.

Genotypes	Pod damage (%)	Damage score	Resistance rating *
ICPL 98001	49.25 (44.56)	2.40	Intermediate
ICPL 98002	51.00 (45.57)	2.55	Intermediate
ICPL 98003	5.80 (13.91)	0.25	Highly resistant
ICPL 98008	6.77 (14.73)	0.35	Highly resistant
ICPL 98012	24.50 (29.61)	1.24	Moderately resistant
ICPL 88034	68.00 (56.71)	3.45	Susceptible
CV	2.10		
SE	11.0		
CD	5.648		

*% Pod damage	Resistance rating
0 – 20	1= Highly resistant
21 – 40	2 = Moderately resistant
41 – 60	3 = Intermediate
61 – 80	4 = Susceptible
81 – 100	5 = Highly susceptible

Values in parantheses are arcsin percentage values

Based on the pod damage the genotypes were given the resistance rating 1-5. The genotypes possessing the resistance rating 1 were considered highly resistant, 2-moderately resistant, 3-intermediate, 4-susceptible and 5-highly susceptible. In the present study ICPL 98003 and ICPL 98008 which recorded the resistance rating of 0.25 and 0.35 were categorized as highly resistant and the moderatly resistant genotype ICPL 98012 recorded 1.24 damage score. The genotypes ICPL 98001 and ICPL 98002 recording the damage score of 2.40 and 2.55 were grouped under intermediate type and the susceptible genotype ICPL 88034 recorded 3.45 damage score. In the present study none of the genotypes were highly susceptible to the pest attack (Table 3).

4.1.2 Screening of pigeonpea genotypes under greenhouse conditions

Cage technique was employed to screen pigeonpea genotypes for resistance to the pod borer under greenhouse conditions by subjecting them to uniform insect pressure at 50% flowering stage and the results recorded on the following parameters are presented in Table 4.

4.1.2.1 Total number of pods

Observations recorded on the total number of pods in each genotype showed maximum number of pods in ICPL 88034 (23.00) and

Table-4 : Relative susceptibility of pigeonpea genotypes to spotted pod borer *Maruca vitrata* at the flowering stage (10 larvae/plant) under greenhouse conditions

Genotypes	Total number of pods/plant	Number of Damaged pods/plant	Pod damage (%)	Larval weight (mg)	Larval mortality (No.)	Grain yield (g/plant)
ICPL 98001	16.00	4.45	28.36 (32.12)	60.08	2.00	1.85
ICPL 98002	20.00	6.45	32.47 (34.72)	62.27	2.25	2.05
ICPL 98003	14.75	2.47	17.40 (24.51)	30.77	2.50	3.37
ICPL 98008	12.00	2.53	21.74 (27.65)	31.95	2.50	2.30
ICPL 98012	15.00	4.65	31.65 (34.17)	27.62	2.50	2.42
ICPL 88034	23.00	7.35	32.42 (34.69)	70.20	2.50	1.52
CV	15.17	6.28	9.96	4.64	54.67	0.12
SE	1.27	0.15	10.59	1.10	0.65	0.11
CD	3.78	0.43	4.63	3.30	1.96	0.37

ICPL 98002 (20.00) which were on par with each other. Significantly lowest number of pods were recorded in ICPL 98008 (12.0) and ICPL 98003 (14.75). The number of pods recorded in ICPL 98001 and ICPL 98012 were 16.00 and 15.00 respectively.

4.1.2.2 Damaged pods

The number of pods damaged by spotted pod borer were highest in ICPL 88034 (7.35) and ICPL 98002 (6.45), whereas the damaged pods recorded in ICPL 98012 and ICPL 98001 were 4.65 and 4.45 respectively. Significantly less number of pods were damaged in ICPL 98003 (2.47) and ICPL 98008 (2.53).

Significantly highest pod damage was recorded in ICPL 98002 (32.47 %) and ICPL 88034 (32.42 %) followed by ICPL 98012 (31.65 %) and ICPL 98001 (28.36 %). The pod damage was found to be lowest in ICPL 98003 (17.40 %) followed by ICPL 98008 (21.74 %).

4.1.2.3 Larval weight gain

The larvae fed on ICPL 88034 gained maximum weight (70.20 mg) where as it was lowest in genotype ICPL 98012 (27.62 mg). The larval weight gain recorded in ICPL 98002 (62.27 mg) and ICPL 98001 (60.08 mg) was on par with each other. The larval weight

gain in ICPL 98003 and ICPL 98008 was 30.77mg and 31.95 mg respectively.

4.1.2.4 Larval mortality

The larval mortality observed on test genotypes ranged from 2.00 to 2.50 and no significant difference was observed between the treatments.

4.1.2.5 Grain yield

The grain yield recorded per plant in pigeonpea genotypes varied from 1.52 g in ICPL 88034 to 3.37 g in ICPL 98003. The grain yield obtained from ICPL 98012 (2.42 g), ICPL 98008 (2.30 g) and ICPL 98002 (2.05 g) was on par with each other. The grain yield obtained from ICPL 98001 was 1.85 g/plant.

4.1.3 Screening of pigeonpea genotypes in the laboratory

First instar larvae of *M.vitrata* were fed on the flowers of six pigeonpea genotypes under laboratory conditions and the following parameters were observed (Table 5).

Table-5 : Growth and development of *Maruca vitrata* larva reared on flowers of six pigeonpea genotypes under laboratory conditions

Genotype	Mass of food consumed by the larva (mg)	Mass of faeces excreted by the larva (mg)	Mass of larva before feeding (mg)	Mass of larva after feeding (mg)	Increase in mass (mg)	Growth rate (%)	Pupation (%)	Pupal weight (mg)
ICPL 98001	65.30	16.20	2.00	56.70	54.50	254.72	69.25	41.10
ICPL 98002	41.70	15.10	2.00	48.30	46.30	270.05	70.25	34.80
ICPL 98003	43.00	23.30	2.00	33.30	31.10	112.45	49.75	11.30
ICPL 98008	38.00	16.80	2.00	35.00	33.00	136.79	45.50	20.00
ICPL 98012	69.30	22.50	2.00	34.70	32.70	116.38	41.75	31.50
ICPL 88034	77.00	28.00	2.00	66.80	64.80	276.47	73.0	48.30
CV	4.00	2.16	0.001	5.32	2.00	10.11	2.76	0.12
SE	1.50	2.13	0.010	2.30	1.08	0.104	0.009	2.30
CD	1.20	6.40	NS	1.50	7.40	30.05	8.22	6.84

4.1.3.1 Mass of food consumed by the larvae

Highest food consumption was recorded on ICPL 88034 (77.00 mg) followed by ICPL 98003 (69.30 mg) and ICPL 98002 (65.30 mg) which were on par with each other. Lowest food consumption was recorded with ICPL 98008 (38.00 mg) followed by ICPL 98001 (41.70 mg) and ICPL 98012 (43.00 mg).

4.1.3.2 Mass of faeces

Mass of faeces excreted by the larvae was highest when fed on ICPL 88034 (28.00 mg) followed by ICPL 98003 (23.30 mg) and ICPL 98012 (22.50 mg). Lowest mass of excreta was recorded with ICPL 98002 (15.10 mg) followed by ICPL 98001 (16.20 mg) and ICPL 98008 (16.80 mg) which were on par with each other.

4.1.3.3 Mass of larvae

The first instar larvae before releasing on the test genotypes did not differ in their weights and all of them weighed 2.00mg whereas they differed in their weight after feeding on different pigeonpea genotypes. Significant and highest larval weight was recorded on ICPL 88034 (66.80 mg) compared to those reared on ICPL 98001 (56.70 mg), ICPL98002

(48.30 mg), ICPL 98008 (35.00 mg) and ICPL 98012 (34.70 mg). Lowest larval mass was recorded with ICPL 98003 (33.30 mg).

4.1.3.4 Increase in larval mass

The increase in larval weight was highest on ICPL 88034 (64.80 mg) followed by ICPL 98001 (54.50 mg) and ICPL 98002 (46.30 mg). Lowest larval weight gain was observed on ICPL 98003 (31.30 mg) followed by ICPL 98012 (32.70 mg) and ICPL 98008 (33.00 mg).

4.1.3.5 Growth rate percentage

Larva reared on ICPL 88034 recorded highest growth rate (276.47 %) followed by ICPL 98002 (270.05%) and ICPL 98001 (254.72%). Significantly lowest growth rate was recorded on ICPL 98003 (112.45%) followed by ICPL 98012 (116.38%) and ICPL 98008 (136.79%).

4.1.3.6 Pupation percentage

Highest pupation was recorded on ICPL 88034 (73.00%) followed by ICPL 98002 (70.25%) and ICPL 98001 (69.25%), whereas lowest pupation was recorded on ICPL 98003 (41.75%) followed by ICPL 98008 (45.50%) and ICPL 98012 (49.75%).

4.1.3.6 Pupal weight

Maruca reared on ICPL 88034 recorded highest pupal mass (48.30 mg) followed by ICPL 98001 (41.10 mg), ICPL 98002 (34.80 mg) and ICPL 98012 (31.50 mg). Lowest pupal mass was recorded on ICPL 98003 (11.30 mg) and ICPL 98008 (20.00 mg).

4.1.3.7 Efficiency of conversion of ingested food (ECI) in to body matter

Efficiency of conversion of ingested food into body matter was highest with ICPL 98001 (131.65%) followed by ICPL 98002 (94.00%), ICPL 98008 (90.72%) and ICPL 88034 (87.95%) whereas lowest ECI was recorded on ICPL 98003 (44.98%) followed by ICPL 98012 (76.57%) (Table 6).

4.1.3.8Efficiency of conversion of digested food (ECD) into body matter

Efficiency of conversion of digested food into body matter was highest on ICPL 98001 (222.45%) followed by ICPL 98008 (208.66%). Lowest ECD was recorded on ICPL 98003 (67.50%). The ECD recorded on other genotypes *viz.*, ICPL 98002, 88034 and 98012 was 126.45%, 134.01% and 161.25% respectively.

Table-6 : Consumption and utilization of flowers of six pigeonpea genotypes by *Maruca vitrata* larvae

Genotype	ECI %	ECD %	AD %	CI
ICPL 98001	131.65	222.45	60.55	1.94
ICPL 98002	94.00	126.45	130.60	2.87
ICPL 98003	44.98	67.50	66.00	2.51
ICPL 98008	90.72	208.66	51.17	1.59
ICPL 98012	76.57	161.25	47.90	1.51
ICPL 88034	87.95	134.01	63.82	3.30
CV	7.47	25.30	5.13	1.03
SE	0.17	0.33	0.14	0.16
CD	22.20	75.18	15.26	5.45

4.1.3.8Approximate digestibility (AD)

Approximate digestibility was highest in the larvae fed on ICPL 98002 (130.60%) and lowest on ICPL 98012 (47.90%). Approximate digestibility recorded on ICPL 98003, ICPL 88034, ICPL 98001 and ICPL 98008 was 66.00%, 63.82%, 60.55% and 51.17% respectively.

4.1.3.9Consumption index (CI)

Highest consumption index was recorded in ICPL 88034 (3.30) followed by ICPL 98002 (2.87) and ICPL 98003 (2.51). Lowest CI was recorded on ICPL 98012 (1.51) followed by ICPL 98008 (1.59) and ICPL 98001 (1.94).

4.2.1 Morphological characters of pigeonpea genotypes

The following morphological characters observed in the pigeonpea genotypes are presented in Table7.

4.2.1.1 Growth habit

The genotypes ICPL 98001, 98002 and 98003 showed determinate type of growth habit while indeterminate type growth habit was observed in ICPL 98008, 98012 and 88034.

Table-7 : Morphological characters of selected short duration pigeonpea genotypes

Genotype	Growth habit	Time required for pod maturity (days)	Time required to complete flowering (days)	Pods exposed above / below foliage	Podding habit	Pod length (cm)	Pod width (cm)	Pod wall thickness (mm)
ICPL 98001	Determinate	53.75	9.50	Above the foliage	Non clustered	4.85	0.90	2.50
ICPL 98002	Determinate	47.00	6.00	Above the foliage	Non clustered	5.17	0.95	2.70
ICPL 98003	Determinate	57.25	9.75	Above the foliage	Clustered	5.10	0.87	3.42
ICPL 98008	Indeterminate	63.00	15.75	Above the foliage	Non clustered	5.97	0.69	3.17
ICPL 98012	Indeterminate	57.75	12.25	Below the foliage	Clustered	5.20	0.95	2.37
ICPL 88034	Indeterminate	86.50	18.00	Below the foliage	Non clustered	7.00	0.48	1.27
CV		0.06	0.10			4.30	0.10	0.15
SEM		1.90	0.61			0.23	4.09	0.19
CD		5.65	1.82			0.35	0.121	0.58

4.2.1.2 Time required for complete flowering

The pigeonpea genotype ICPL 98002 took less time to complete flowering (6.00 days) followed by ICPL 98001 (9.50 days) and ICPL 98003 (9.75 days). The genotype ICPL 88034 took more time to complete the flowering (18.00 days) followed by ICPL 98008 (15.75 days) and ICPL 98012 (12.25 days).

4.2.1.3 Time required for pod maturity

The time required for pod maturity was significantly lowest in ICPL 98002 (47.00 days) whereas it was highest in ICPL 88034 (86.50 days). The pod maturity time required in ICPL 98001 (53.75 days), ICPL 98003 (57.25 days) and ICPL 98012 (57.75 days) was on par with each other. The time required for pod maturity in ICPL 98008 (63.00 days) was intermediate.

4.2.1.4 Pods exposed above or below the foliage

Among the six pigeonpea genotypes, four genotypes *viz.*, ICPL 98001, 98002, 98003 and 98008 consists of pods held above the canopy and ICPL 98012 and ICPL 88034 with pods held within the canopy.

4.2.1.5 Podding habit

Clustered type of podding habit was observed in ICPL 98003 and ICPL 98012 genotypes. In the rest of the genotypes *viz.*, ICPL 98001, ICPL 98002, 98008 and 88034 non-clustered type was observed.

4.2.1.6 Pod length

The differences in the length of pods observed in six pigeonpea genotypes was significant and the genotype ICPL 88034 (7.00 cm) recorded the longest pod length (7.00 cm) followed by ICPL 98008 (5.97 cm). Lowest pod length was recorded in ICPL 98001 (4.85 cm). The pod lengths recorded in other genotypes *viz.*, ICPL 98002, ICPL 98003 and ICPL 98012 were 5.17 cm, 5.10 cm and 5.20 cm respectively.

4.2.1.7 Pod width

The pod width was significantly highest in ICPL 98002 (0.95 cm) and ICPL 98012 (0.95 cm) followed by ICPL 98001 (0.90 cm) and ICPL 98003 (0.87 cm). The pod width was significantly lowest in ICPL 88034 (0.48 cm) and ICPL 98008 (0.69 cm).

4.2.1.8 Pod wall thickness

The pod wall thickness was significantly more in ICPL 98003 (3.42 mm) followed by ICPL 98008 (3.17 mm). Lowest pod wall thickness was observed in ICPL 88034 (1.27 mm). The pod wall thickness observed in other genotypes *viz.*, ICPL 98001, ICPL 98002, and ICPL 98012 was 2.50 mm, 2.70 mm and 2.37 mm respectively.

4.2.1.9 Trichome density of pigeonpea genotypes

The trichome density was observed on veins, upper surface and lower surface of the leaves and the results are presented in Table 8.

The number of trichomes on veins of six pigeonpea genotypes varied significantly and the results revealed significantly highest density on the veins of ICPL 98003 (500.00) followed by ICPL 98008 (416.25), ICPL 98012 (397.50) and ICPL 98002 (367.50). Lowest trichome density was recorded on ICPL 88034 (250.00) followed by ICPL 98001 (290.00).

The trichome density present on the upper surface of the leaves was significantly highest on ICPL 98003 (390.00) followed by ICPL 98012 (307.50) and ICPL 98008 (300.00). Lowest trichome

Table-8 : Trichome length and density on leaves and pods of pigeonpea genotypes

Genotype	Trichome density on leaves			Trichome density on Pods	Trichome length (mm)	
	On veins	Upper surface of leaf	Lower surface of leaf		On leaf	Pod
ICPL 98001	290.00	170.00	240.00	317.50	2.23	5.13
ICPL 98002	367.50	232.50	297.50	260.00	2.44	5.38
ICPL 98003	500.00	390.00	452.00	405.00	3.54	6.01
ICPL 98008	416.25	300.00	440.00	442.50	3.04	5.87
ICPL 98012	397.50	307.50	430.00	365.00	2.93	5.66
ICPL 88034	250.00	197.50	257.50	243.75	1.66	2.01
CV	5.97	7.93	7.73	0.074	0.0006	0.029
SE	11.06	10.50	13.65	12.64	0.089	0.073
CD	32.88	31.30	40.57	37.58	0.26	0.21

density was recorded on ICPL 98001 (170.00) followed by ICPL 88034 (197.50) and ICPL 98002 (232.50).

The trichome density was highest on the lower surface of leaves of ICPL 98003 (452.00) followed by ICPL 98008 (440.00) and ICPL 98012 (430.00). Lowest trichome density was recorded on ICPL 98001 (240.00) followed by ICPL 88034 (257.50) and ICPL 98002 (297.50).

Highest trichome density on pods was recorded on ICPL 98008 (442.50) followed by ICPL 98003 (405.00) and ICPL 98012 (365.00). Lowest trichome density was recorded on ICPL 88034 (243.75) followed by ICPL 98002 (260.00) and ICPL 98001 (317.50).

4.2.1.9Trichome length of pigeonpea genotypes

Observations recorded on trichome length on leaves of six pigeonpea genotypes revealed significantly highest trichome length on ICPL 98003 (3.54 mm) followed by ICPL 98008 (3.04 mm) and ICPL 98012 (2.93 mm). Lowest trichome length was recorded on ICPL 88034 (1.66 mm) followed by ICPL 98001 (2.23 mm) and ICPL 98002 (2.44 mm).

The length of the trichomes on pods of six pigeonpea genotypes was observed and the results revealed highest trichome length on ICPL 98003 (6.01 mm) followed by ICPL 98008 (5.87 mm) and ICPL 98012 (5.66 mm). Lowest trichome length was recorded on ICPL 88034 (2.01 mm). The trichome lengths recorded in ICPL 98001 and ICPL 98002 were 5.13 mm and 5.38 mm respectively.

4.2.2 Biochemical constituents of pigeonpea genotypes

The biochemical constituents *viz.*, sugars, phenols and proteins present in the leaves, flowers and pods were estimated in six pigeonpea genotypes and the results are presented in Table 9.

4.2.2.1 Sugars

The sugars present in leaves, flowers and pods differed significantly. The sugar content found in the flowers was more than the leaves and pods.

The sugar content of leaves was highest in ICPL 98002 (5.93%) and lowest in ICPL 98003 (5.21%). The sugar content recorded in other genotypes *viz.*, ICPL 98001, ICPL 98008, ICPL 98012 and ICPL 88034 were 5.88%, 5.62%, 5.66%, 5.90% respectively.

Table-9 : Concentration of sugars, proteins and phenols in various parts of six pigeonpea genotypes

Genotype	Sugars (%)			Proteins (%)			Phenols (%)		
	Leaves	Flowers	Pods	Leaves	Flowers	Pods	Leaves	Flowers	Pods
ICPL 98001	5.88	18.14	10.60	29.71	18.83	22.97	2.35	5.53	8.12
ICPL 98002	5.93	18.58	9.81	32.23	18.59	23.07	2.00	5.23	8.57
ICPL 98003	5.21	14.68	7.00	26.15	15.55	16.51	3.02	6.45	9.32
ICPL 98008	5.62	17.86	8.61	26.74	16.59	19.97	2.62	6.00	9.31
ICPL 98012	5.66	18.35	9.25	29.71	17.27	20.93	2.40	6.05	9.15
ICPL 88034	5.90	22.05	9.57	30.93	18.62	25.51	1.75	5.08	7.37
CV	0.55	0.60	2.36	5.39	4.04	4.45	10.21	4.99	2.88
SE	0.02	0.05	0.11	0.78	0.35	0.48	0.12	0.14	0.12
CD	0.05	0.16	0.32	2.34	1.07	1.44	0.36	0.43	0.38

The genotype ICPL 88034 recorded highest sugar content of 22.05% in flowers followed by ICPL 98002 (18.58%), ICPL 98012 (18.35%), ICPL 98001 (18.14%) and ICPL 98008 (17.86%). Lowest sugar content was recorded in ICPL 98003 (14.68%).

Highest sugar content was recorded in pods of ICPL 98001 (10.60%) while lowest was recorded in ICPL 98003 (7.00%). The sugar content of other genotypes *viz.*, ICPL 98002, ICPL 98008, ICPL 98012 and ICPL 88034 was 9.81%, 8.61%, 9.25% and 9.57% respectively.

4.2.2.2 Proteins

Protein content of leaves, flowers and pods of six pigeonpea genotypes differed significantly. The protein content in leaves was greater than flowers and pods.

Among the six genotypes, highest protein content in leaves was recorded in ICPL 98002 (32.23%) and ICPL 88034 (30.93%) and in the rest of genotypes it ranged from 26.15% to 29.71%.

Highest protein content in flowers was recorded in ICPL 98001 (18.83%) while it was lowest in ICPL 98003 (15.55%). The protein content of other genotypes *viz.*, ICPL 98002, ICPL 98008, ICPL 98012

and ICPL 88034 was 18.59%, 16.59%, 17.27% and 18.62% respectively.

Protein content in pods was highest in ICPL 88034 (25.51%) followed by ICPL 98002 (23.07%), ICPL 98001 (22.97%), ICPL 98012 (20.93%) and ICPL 98008 (19.97%). Lowest protein content was recorded in ICPL 98003 (16.51%).

4.2.2.3 Phenols

Phenol content estimated in leaves, flowers and pods of pigeonpea genotypes differed significantly (Table 9). The phenol content in pods was greater than leaves and flowers.

The total phenols estimated in leaves of six pigeonpea genotypes showed significantly highest phenol content in ICPL 98003 (3.02%) followed by ICPL 98008 (2.62%), whereas lowest phenol content was recorded in ICPL 88034 (1.75%). In other genotypes *viz.*, ICPL 98001, 98002 and ICPL 98012 it varied from 2.00 to 2.62 per cent.

Highest phenol content in flowers was recorded in ICPL 98003 (6.45%) followed by ICPL 98012 (6.05%). Low phenol content was recorded in ICPL 88034 (5.08%). In other genotypes it ranged between 5.23 to 6.00 per cent.

Among the six genotypes, highest phenol content was recorded in the pods of ICPL 98003 (9.32) followed by ICPL 98008 (9.31) and ICPL 98012 (9.15). Lowest phenol content was recorded in ICPL 88034 (7.37) followed by ICPL 98001 (8.12) and ICPL 98002 (8.57).

4.2.3 Correlation studies

Correlation coefficients were worked out between dependent and independent variables in field, green house and laboratory conditions to know their relationships.

4.2.3.1 Correlation studies between physico – chemical parameters and pod damage (%) in the field

Correlation coefficient were workedout between pod damage and physico-chemical characters of pigeonpea genotypes (Table.10, 11). Among the physical characters, pod wall thickness (-0.84), trichomes length on leaves (-0.95) and pods (-0.96) and trichome density on leaves (-0.95) showed a highly significant negative relation with pod damage (%). Other physical parameters *viz.*, pod length, width and trichome density on pods did not show significant relation. The correlation studies (Table11) made with chemical constituents revealed a significant correlation with pod damage. Significant and positive correlation was observed between pod damage (%) and sugars in leaves (0.85), flowers

Table-10 : Simple correlation coefficients between morphological characters of pigeonpea genotypes and per cent pod damage under field conditions

Sl. No.	Morphological characters	Pod damage (%)
1.	Pod length	0.35
2.	Pod width	-0.30
3.	Pod wall thickness	-0.84*
4.	Trichome length on leaf	-0.95**
5.	Trichome length on pod	-0.96**
6.	Trichome density on leaf	-0.95**
7.	Trichome density on pod	0.78

* Significant at 0.05%

** Significant at 0.01%

Table-11 : Simple correlation coefficients between chemical constituents of pigeonpea genotypes and per cent pod damage under field conditions

Sl. No.	Chemical characters	Pod damage (%)
1.	Sugars in leaf	0.85*
2.	Sugars in flower	0.80
3.	Sugars in pod	0.77
4.	Proteins in leaf	0.87*
5.	Proteins in flower	0.93**
6.	Proteins in pod	0.93**
7.	Phenols in leaf	-0.92**
8.	Phenols in flower	-0.94**
9.	Phenols in pod	-0.94**

* Significant at 0.05%

** Significant at 0.01%

Table-12 : Simple linear regression analysis between physico-chemical characters of pigeonpea genotypes and per cent pod damage under field conditions

Sl. No.	Variable	Regression equation	r^2
1.	Pod wall thickness (X1)	Y1 = 108.3934 - 28.80520 X 1	0.71
2.	Trichome density on leaf (X2)	Y1= 123.0058 - 0.08826 X 2	0.91
3.	Trichome density on pod (X3)	Y1 =139.9919 - 0.31205 X 3	0.92
4.	Trichome length on leaf (X4)	Y1 = 131.6188 – 36.8935 X 4	0.90
5.	Sugars in leaf (X5)	Y1= -421.1603 +79.891 X 5	0.72
6.	Proteins in leaf (X6)	Y1= -243.4587 + 9.49491 X 6	0.76
7.	Proteins in flower (X7)	Y1= -280.6367 + 17.91503 X 7	0.86
8.	Proteins in pod (X8)	Y1 = 131.9735 + 7.73233 X 8	0.87
9.	Phenols in leaf (X9)	Y1 = 158.4997 - 52.73536 X 9	0.84
10.	Phenols in flower (X10)	Y1 = 296.1270 - 45.76128 X 10	0.89
11.	Phenols in pod (X11)	Y1 = 301.2623 - 30.90767 X 11	0.88

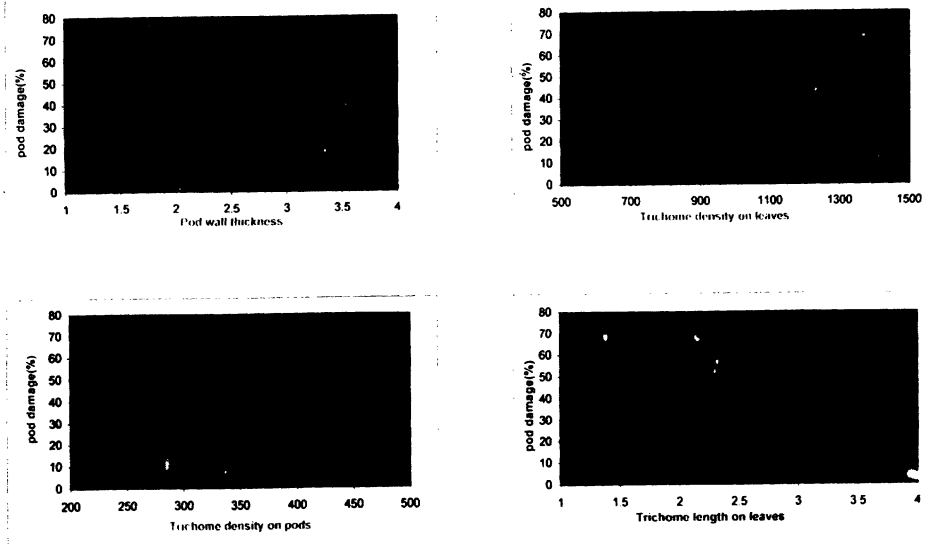


Fig 2-5 :Regression model of morphological charecters of pigeonpea genotypes with pod damage (%) under field conditions

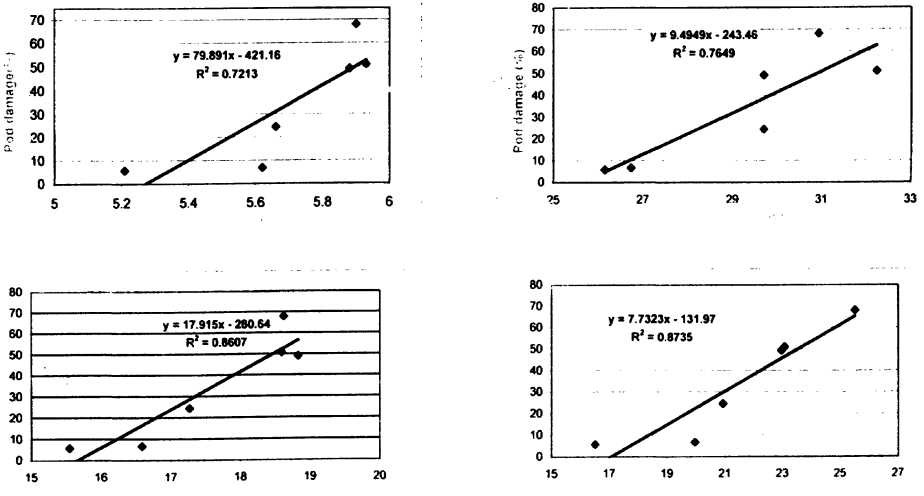
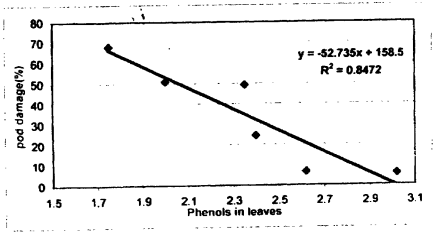
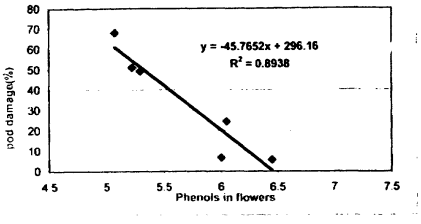


Fig 6-9: Regression model of chemical constituents of pigeonpea genotypes with pod damage(%) under field conditions





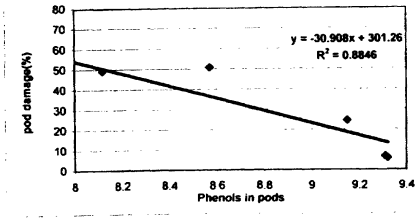


Fig 10-12: Regression model of phenols in pigeonpea genotypes with pod damage (%) under field conditions

(0.80) and pods (0.77). Similarly proteins found in leaves (0.87), flowers (0.93) and pods (0.93) also influenced a significant positive correlation with pod damage (%). Phenols in leaves (-0.92), flowers (-0.94) and pods (-0.94) showed a highly significant negative correlation with pod damage. Simple linear regression analysis carried out between pod damage (%) and physico-chemical parameters of pigeonpea genotypes also showed a significant relation of pod damage with physico-chemical parameters of pigeonpea genotypes (Table 12, Fig. 2-12).

4.2.3.2 Correlation studies between physico – chemical parameters of pigeonpea genotypes with larval weight gain, larval mortality, pod damage (%) by *Maruca vitrata* and grain yield under greenhouse conditions

Correlation studies undertaken between larval weight gain and physico - chemical parameters of pigeonpea genotypes (Table 13, 14) revealed that trichome length and density on leaves (-0.94 and-0.91) and trichome density on pods (-0.95) had negative significant relation with larval weight gain. The other morphological parameters did not exert any significant effect. The larval weight gain showed a significant positive correlation with proteins in leaves (0.81), flowers (0.89) and pods (0.86), where as it was negative and significant with phenols in leaves (-0.84), flowers (-0.93) and pods (-0.93).

Table-13 : Simple correlation coefficients between morphological characters of pigeonpea genotypes and larval weight gain, larval mortality, per cent pod damage by *Maruca vitrata* and grain yield under greenhouse conditions

Sl. No.	Morphological characters	Larval weight gain	Larval mortality	Pod damage (%)	Grain yield
1.	Pod length	0.30	0.53	0.21	-0.49
2.	Pod width	-0.29	-0.42	-0.03	0.44
3.	Pod wall thickness	-0.72	0.007	-0.78	0.79
4.	Trichome length on leaf	-0.94**	0.62	-0.74	0.87*
5.	Trichome length on pod	-0.95**	0.36	-0.80	0.70
6.	Trichome density on leaf	-0.91**	0.36	-0.77	0.94**
7.	Trichome density on pod	-0.73	-0.09	-0.52	0.69

* Significant at 0.05%

** Significant at 0.01%

Table-14 : Simple correlation coefficients between chemical constituents of pigeonpea genotypes and larval weight gain, larval mortality, per cent pod damage by *Maruca vitrata* and grain yield under greenhouse conditions

Sl. No.	Chemical characters	Larval weight gain	Larval mortality	Pod damage (%)	Grain yield
1.	Sugars in leaf	0.79	-0.52	0.86*	-0.95**
2.	Sugars in flower	0.70	-0.003	0.79	-0.91**
3.	Sugars in pod	0.70	-0.69	0.81*	-0.87*
4.	Proteins in leaf	0.81*	-0.39	0.94**	-0.73
5.	Proteins in flower	0.89*	-0.63	0.85*	-0.90*
6.	Proteins in pod	0.86*	-0.35	0.86*	-0.97**
7.	Phenols in leaf	-0.84*	0.19	-0.89*	0.89*
8.	Phenols in flower	-0.93**	0.40	-0.79	0.90*
9.	Phenols in pod	-0.93**	0.34	-0.63	0.82*

* Significant at 0.05%

** Significant at 0.01%

No significant relation was found between larval mortality and various physico chemical parameters of pigeonpea genotypes (Table 13,14).

Correlation coefficients worked out between per cent pod damage and physical parameters (Table 13, 14) did not show any significant relation while among the chemical constituents positive and significant correlation was observed between pod damage and sugars in leaves (0.86), pods (0.81), proteins in leaves (0.94), flowers (0.85) and pods (0.86) while phenols in leaves (-0.89) showed negative and significant correlation with pod damage.

Correlation studies made between physico – chemical parameters and grain yield showed that trichomes length (0.87) and density (0.94) on leaves had positive and significant correlation with grain yield and significant negative correlation with sugars in leaves (-0.95), flowers (-0.91), pods (-0.87), proteins in flowers (-0.90) and pods (-0.97) whereas the relation was significant and positive with phenols in leaves (0.89), flowers (0.90) and pods (0.82) (Table 14).

Simple linear regression analysis also resulted in significant relation of physico - chemical parameters with larval weight gain, pod damage and grain yield (Tables 15,16,17) (fig.13-21).

Table-15 : Simple linear regression analysis between physico- chemical characters of pigeonpea genotypes and larval weight gain by *Maruca vitrata* under greenhouse conditions

Sl. No.	Variable	Regression equation	r^2
1.	Trichome density on leaf (X1)	Y1 = 111.6433 - 0.06411 X 1	0.88
2.	Trichome density on pod (X2)	Y1= 124.2056 - 0.22734 X 2	0.90
3.	Trichome length on leaf (X3)	Y1 = 115.8937 - 86.03991 X 3	0.83
4.	Proteins in leaf (X4)	Y1= -143.2592 + 6.51077 X 4	0.65
5.	Proteins in flower (X5)	Y1= -176.3857 + 12.71886 X 5	0.79
6.	Proteins in pod (X6)	Y1= -66.5962 + 5.29208 X 6	0.74
7.	Phenols in leaf (X7)	Y1 = 131.7412 - 35.89512 X 7	0.71
8.	Phenols in flower (X8)	Y1 = 238.7192 - 33.47191 X 8	0.87
9.	Phenols in pod (X9)	Y1 = 242.0849 - 22.56210 X 9	0.86

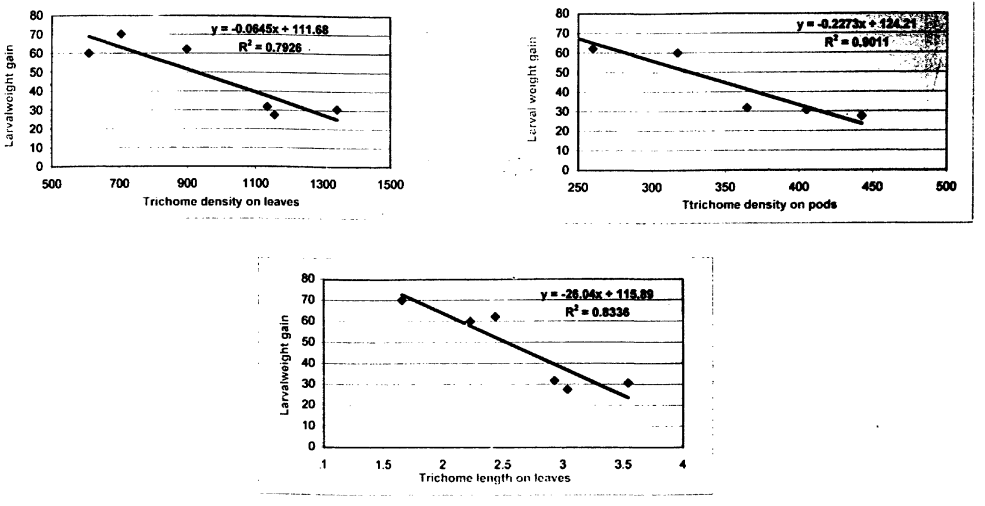


Fig 13-15 : Regression model of trichomes of pigeonpea genotypes with larval weight gain by *Maruca vitrata* under greenhouse conditions

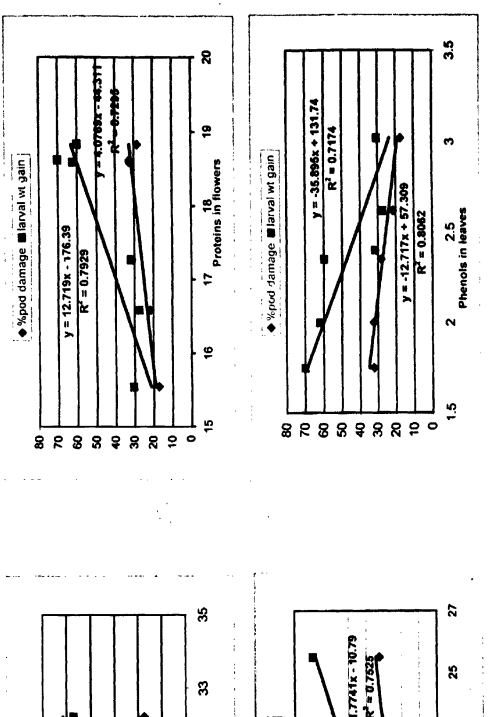
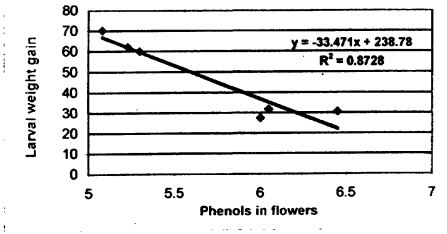


Fig 16-19 : Regression model of chemical constituents of pigeonpea genotypes with larval weight gain by *Maruca vitrata* and pod damage (%) under greenhouse conditions



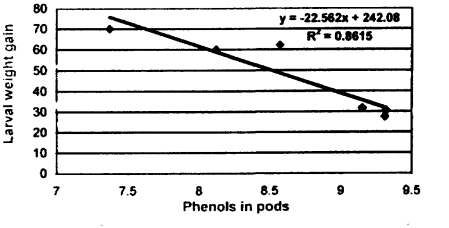
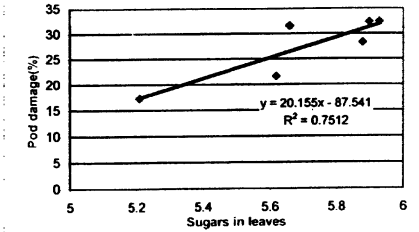


Fig 20-21 : Regression model of phenols of pigeonpea genotypes with larval weight gain by *Maruca vitrata* under greenhouse conditions



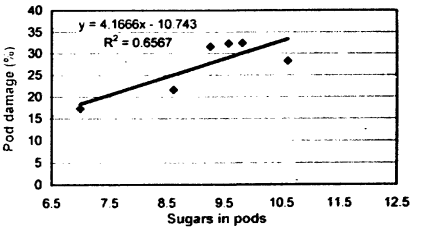


Fig 22-23: Regression model of sugars of pigeonpea genotypes with pod damage (%) by *Maruca vitrata* under greenhouse conditions

Table-16 : Simple linear regression analysis between chemical constituents of pigeonpea genotypes and per cent pod damage by *Maruca vitrata* under greenhouse conditions

Sl. No.	Variable	Regression equation	r^2
1.	Sugars in leaves (X1)	Y1= -87.5408 + 20.15453 X 1	0.75
2.	Sugars in pods (X2)	Y1= -10.7426 + 4016659 X 2	0.65
3.	Proteins in leaves (X3)	Y1= -46.8717 + 2.53758 X 3	0.89
4.	Proteins in flowers(X4)	Y1 = -44.3107 + 4.07685 X 4	0.72
5.	Proteins in pods (X5)	Y1 = -10.7903 + 1.77405 X 5	0.75
6.	Phenols in leaves (X6)	Y1 = 57.3091 - 12.71672 X 6	0.80

Table-17 : Simple linear regression analysis between physico-chemical characters of pigeonpea genotypes and grain yield under greenhouse conditions

Sl. No.	Variable	Regression equation	r^2
1.	Trichome density on leaf (X1)	Y1= 0.2443 + 0.00200 X 1	0.76
2.	Trichome length on leaf (X2)	Y1 = -0.1290 + 0.89836 X 2	0.88
3.	Sugars in leaf (X3)	Y1= 14.8240 – 2.20568 X 3	0.89
4.	Sugars in flower (X4)	Y1= 6.7751 – 0.24750 X 4	0.83
5.	Sugars in pod (X5)	Y1= 6.3639 – 0.44992 X 5	0.76
6.	Proteins in flower (X6)	Y1 =9.8618 – 0.43301 X 6	0.82
7.	Proteins in pod (X7)	Y1 = 6.5223 – 0.19870 X 7	0.94
8.	Phenols in leaf (X8)	Y1 = -0.7461 + 1.27202 X 8	0.80
9.	Phenols in flower (X9)	Y1 = -3.9721 + 1.08744 X 9	0.82
10.	Phenols in pod (X10)	Y1 = -3.4834 + 0.66378 X 10	0.66

4.2.3.3. Correlation studies between physico – chemical constituents and growth and development of larvae under laboratory conditions

Correlation coefficients carriedout between consumption and utilization of food by the larvae and chemical parameters (Table 18) resulted in significant positive correlation of proteins in flowers with larval weight gain (0.84), growth rate (0.90) and per cent pupation (0.81). Phenols present in flowers showed negative relation with larval weight gain (-0.88) growth rate (-0.95) and per cent pupation (-0.87) whereas sugars did not show any significant effect on consumption & utilization of food by the larvae. Simple linear regression studies (Table 19, 20, 21) also showed similar results (fig. 34,35)

4.3 EFFICACY OF SELECTED INSECTICIDES AGAINST *MARUCA VITRATA* UNDER LABORATORY CONDITIONS

The efficacy of six insecticides comprising two novel insecticides (indoxacarb, spinosad) one conventional insecticide (endosulfan), two biopesticides (*M.anisopleae* and *B. thuringiensis*) and one botanical insecticide (neem fruit extract) was tested against 3rd instar larvae with five doses of each treatment *i.e* insecticide solution of recommended dose, two concentrations below the recommended dose and two

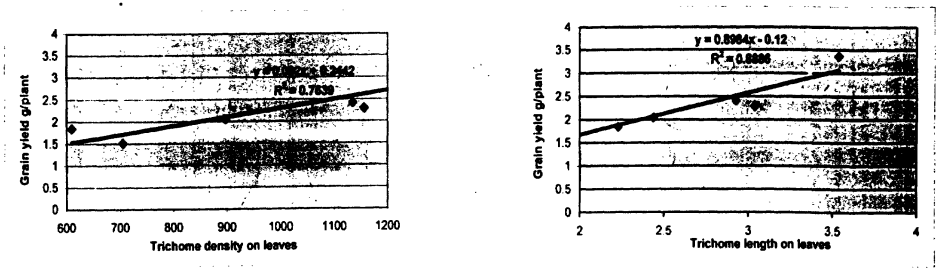


Fig 24-25 :Regression model of trichomes on leaves with grain yield under greenhouse conditions

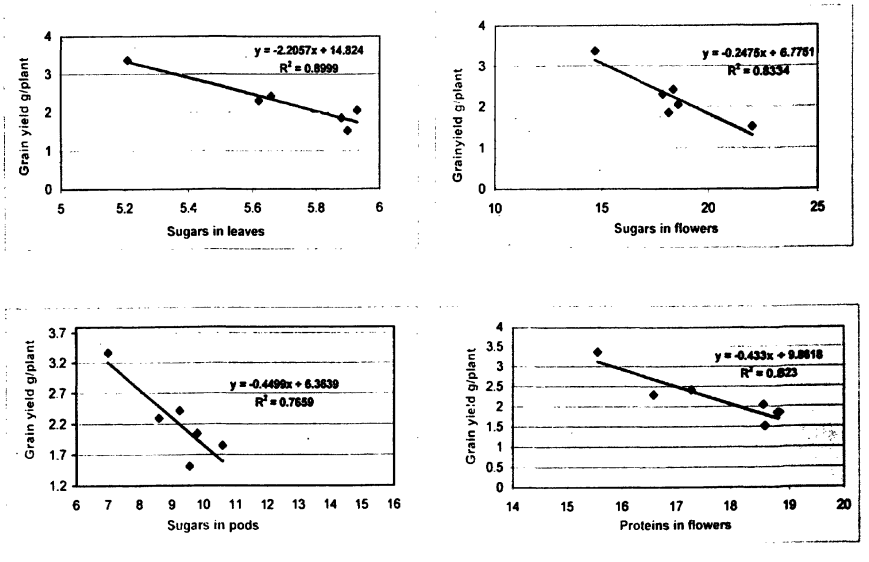


Fig 26-29: Regression model of chemical constituents of pigeonpea genotypes with grain yield under greenhouse conditions

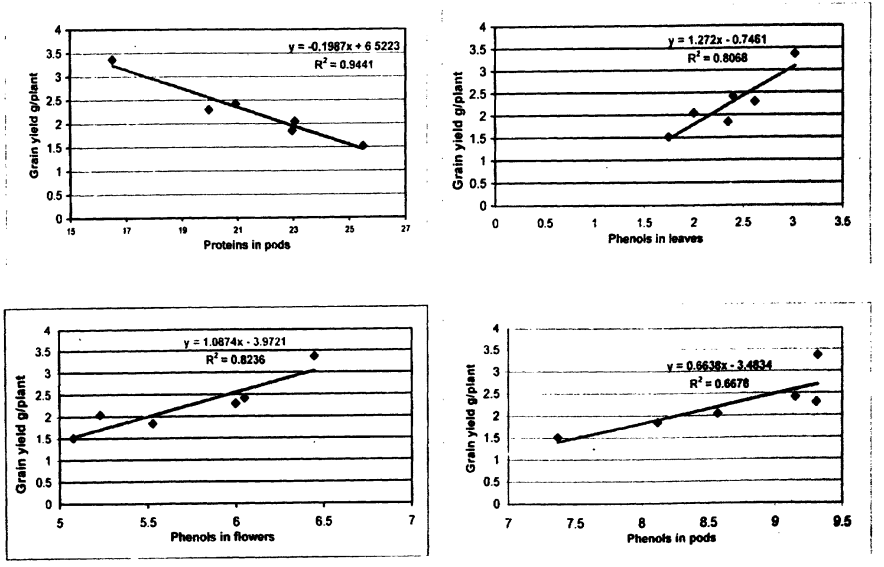


Fig 30-33 : Regression model of chemical constituents of pigeonpea genotypes with grain yield under greenhouse conditions

Table-18 : Simple correlation coefficients between chemical constituents of pigeonpea genotypes and consumption and utilization of food by *Maruca vitrata* under laboratory conditions

Sl. No.	Variable	Mass of food consumed	Mass of faeces	Larval wt. Gain	Growth rate (%)	pupation (%)	Pupal wt.
1.	Sugars in flowers	0.65	0.32	0.78	0.67	0.56	-0.18
2.	Proteins in flowers	0.53	0.17	0.84*	0.90*	0.81*	-0.66
3.	Phenols in flowers	-0.41	0.02	-0.88*	- 0.95**	- 0.87*	0.53

* Significant at 0.05 %
** Significant at 0.01 %

Table-19 : Simple linear regression analysis between chemical constituents of pigeonpea genotypes and larval weight gain by *Maruca vitrata*

Sl. No.	Variable	Regression equation	r^2
1.	Proteins in flower (X1)	Y1= -110.2799 + 8.76320 X 1	0.70
2.	Phenols in flower (X2)	Y1= 176.6654 + 23.22633 X 2	0.788

Table-20: Simple linear regression analysis between chemical constituents of pigeonpea genotypes and growth rate of *Maruca vitrata*

Sl. No.	Variable	Regression equation	r^2
1	Proteins in flower (X1)	Y1= -766.9458 + 54.70398 X 1	0.82
2.	Phenols in flower (X2)	Y1 1019.8667 + 144.21491 X 2	0.90

Table-21 : Simple linear regression analysis between chemical characters of pigeonpea genotypes and per cent pupation of *Maruca vitrata*

Sl. No.	Variable	Regression equation	r^2
1.	Proteins in flower (X1)	Y1 = -92.8883 + 8.59962 X 1	0.66
2.	Phenols in flower (X2)	Y1 = 191.0816 - 23.20878 X 2	0.76

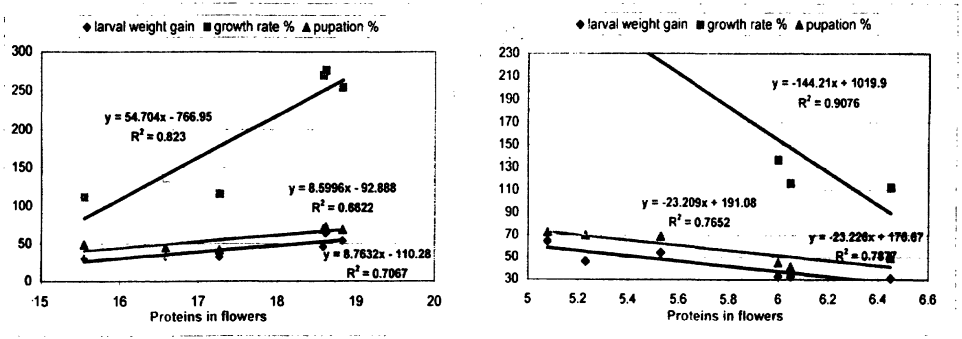


Fig 34-35: Regression model of chemical constituents of pigeonpea genotypes with larval weight gain, growth rate (%), and pupation (%) of *Maruca vitrata* under laboratory conditions

concentrations above the recommended dose. The mortality was observed at 24, 48 and 72 hrs after treatment and the results are presented in (Table 22-27 and fig.36,37,38). The laboratory studies indicated significant differences in efficacy among the insecticides at different doses against *M. vitrata* larvae.

4.3.1 Efficacy of indoxacarb against *M. vitrata*

The mortality of *M. vitrata larvae* with indoxacarb at 24 hrs after treatment was very low (15%) at the lower concentration (0.5 ml/l) and the mortality increased with the increase in concentration and recorded significantly highest mortality (50%) with the highest concentration (1.5 g/l). The mortality was 30 per cent with the recommended dose (1gm/l).

Larval mortality data observed at 48 hrs after treatment ranged from 80 to 92.50 per cent with different concentrations. The recommended dose recorded 85.00 per cent mortality which was significantly different from the lower concentrations.

The mortality data obtained at 72 hrs after treatment revealed 100 per cent mortality at recommended as well as at higher concentrations. Larval mortality was more than 97 per cent even with the lowest

Table-22 : Effect of indoxacarb on 3rd instar larvae of *Maruca vitrata* at different time intervals after treatment under laboratory conditions

Dose (ml/l)	Mortality of *M. vitrata* larva (%)		
	24 hrs	48 hrs	72 hrs
0.50	15.00 (22.50)	80.00 (63.43)	97.50 (85.39)
0.75	22.50 (28.22)	82.50 (65.83)	97.50 (85.39)
1.00	30.00 (33.05)	85.00 (67.50)	100.00 (90.00)
1.25	40.00 (39.23)	90.00 (71.56)	100.00 (90.11)
1.50	50.00 (45.00)	92.50 (78.75)	100.00 (90.00)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
C V	0.120	0.102	0.006
SE	2.02	3.55	2.91
C D	6.10	10.71	NS

Values in parantheses are arcsin percentage values

concentrations. No mortality of larvae was observed in control (Table 22).

4.3.2 Efficacy of spinosad against *M. vitrata*

The experimental results with spinosad after 24hrs of treatment indicated 80 per cent larval mortality at recommended dose (0.3 ml/l) which was significantly higher than the mortality obtained with lower concentrations *viz.*, 0.1 ml/l (42.50%) and 0.2 ml/l (55.00%). The mortality obtained at 0.4 ml/l (82.50%) was not significantly different (80.00%)from the mortality observed at the recommended dose (0.3 ml/l). Significantly highest mortality (92.50%) was obtained with the highest concentrations (0.5 ml/l).

The mortality data observed after 48 hrs of treatment revealed 100 per cent mortality with the highest concentration (0.5 ml/l) followed by 90 per cent with 0.4 ml/l where as the recommnded dose resulted in 82.50 per cent mortality which was significantly higher than those obtained with 0.1 ml (60.00 %) and 0.2 ml concentrations (65.00%).

The data obtained at 72 hrs after treatment did not show significant difference among the different concentrations and resulted in maximum mortality (97.50 to 100 %) of the larvae. No mortality of larvae was observed in control (Table 23).

Table-23 : Effect of spinosad on 3rd instar larvae of *Maruca vitrata* at different time intervals after treatment under laboratory conditions

Dose (ml/ l)	Mortality of *M. vitrata* larva (%)		
	24 hrs	48 hrs	72 hrs
0.10	42.50 (40.67)	60.00 (50.76)	97.50 (85.39)
0.20	55.00 (47.88)	65.00 (53.77)	97.50 (85.39)
0.30	80.00 (63.43)	82.50 (65.46)	97.50 (85.39)
0.40	82.50 (65.46)	90.00 (71.56)	100.00 (90.00)
0.50	92.50 (76.47)	100.00 (90.00)	100.00 (90.00)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
C V	0.083	0.003	0.008
SE	2.45	1.195	3.56
C D	7.40	3.60	NS

Values in parantheses are arcsin percentage values

4.3.3 Efficacy of endosalfan against *M. vitrata*

Endosulfan treatment showed significant difference among the different concentrations after 24 hrs of treatment. The recommended concentration (2 ml/l) resulted in 60 per cent mortality which was on par with the next higher concentration (2.5 ml) but significantly different (72.5% mortality) from the highest concentration (3 ml/l). The lower concentrations *viz.*, 1 ml/l and 1.5 ml/l recorded 40 and 55 per cent mortality respectively.

The mortality of larvae observed with the recommended concentration after 48 hrs of treatment was 92.50 per cent and was on par with the higher concentration. The lowest dose (1 ml/l) resulted in 80 per cent mortality.

No significant difference was found among the different concentrations after 72 hrs of treatment and all the concentrations were found equally effective and recorded 95 to 100 per cent mortality. No mortality of larvae was observed in control (Table 24).

4.3.4 Efficacy of *B. thuringiensis* against *M. vitrata*

B. thuringiensis did not cause the death of larvae at the lowest concentration (0.5 g/l) at 24 hrs after treatment, whereas the

Table-24 : Effect of endosulfan on 3rd instar larvae of *Maruca vitrata* at different time intervals after treatment under laboratory conditions

Dose (ml/lt)	Mortality of *M. vitrata* larva (%)		
	24 hrs	48 hrs	72 hrs
1.00	40.00 (39.23)	80.00 (63.43)	95.00 (80.78)
1.50	55.00 (47.88)	90.00 (74.14)	95.00 (80.78)
2.00	60.00 (50.76)	92.50 (76.17)	97.50 (85.39)
2.50	65.00 (53.77)	97.50 (85.39)	100.00 (90.00)
3.00	72.50 (58.45)	100.00 (90.00)	100.00 (90.00)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
C V	0.05	0.009	0.009
SE	1.30	3.84	3.94
C D	3.94	11.60	NS

Values in parantheses are arcsin percentage values

recommended dose (1.00 g/l), recorded 15 per cent mortality which was on par (20%) with the next higher concentration (1.25 g/l). The highest concentration (1.5 g/l) recorded the maximum mortality (40%).

The mortality obtained after 48 hrs of treatment showed slight improvement and showed 35 per cent mortality at the recommended dose and was significantly different (47.5%) from the highest concentration (1.5 g/l). The mortality obtained with the lowest concentration (0.5 g/l) was 10 per cent which was significantly different (32.5%) from the next higher concentration (0.75 g/l).

B. thuringiensis applied after 72 hrs of treatment resulted in maximum mortality of 85 per cent with the highest concentration (1.5 g/l) and 35 per cent with the lowest concentration (0.5 g/l). The recommended concentration (1 g/l) resulted in 67.5 per cent mortality. No mortality of larvae was observed in control (Table 25).

4.3.5 Efficacy of *M. anisopliae* against *M. vitrata*

Metarhizium did not cause the mortality of larvae at 24 hrs after treatment with different concentrations except at the highest concentration which resulted in 17.5 per cent mortality after 24 hrs of treatment.

Table-25 : Effect of *Bacillus thuringiensis* on 3rd instar larvae of *Maruca vitrata* at different time intervals after treatment under laboratory conditions

Dose (g/l)	Mortality of *M. vitrata* larva (%)		
	24 hrs	48 hrs	72 hrs
0.50	0.00 (0.00)	10.00 (18.43)	35.00 (36.22)
0.75	7.50 (13.82)	32.50 (34.71)	57.50 (49.38)
1.00	15.00 (22.50)	35.00 (36.22)	67.50 (55.28)
1.25	20.00 (26.56)	40.00 (39.23)	75.00 (60.11)
1.50	40.00 (39.23)	47.50 (43.55)	85.00 (67.50)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
C V	0.226	0.007	0.007
SE	2.31	1.21	2.11
C D	6.97	3.65	6.37

Values in parantheses are arcsin percentage values

Table-26 : Effect of *Metarhizium anisopliae* on 3rd instar larvae of *Maruca vitrata* at different time intervals after treatment under laboratory conditions

Dose	Mortality of *M. vitrata* larva (%)		
(g/l)*	24 hrs	48 hrs	72 hrs
1.00	0.00	17.50	22.50
	(0.00)	(24.53)	(24.90)
1.50	0.00	12.50	25.00
	(0.00)	(20.46)	(29.73)
2.00	0.00	17.50	32.50
	(0.00)	(24.53)	(34.55)
2.50	0.00	17.50	35.00
	(0.00)	(24.53)	(36.22)
3.00	17.50	35.00	50.00
	(0.00)	(24.53)	(45.50)
Control	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
C V	0.37	0.1517	0.2579
SE	0.908	1.97	4.39
C D	NS	5.95	4.39

1 gram *Metarhizium anisopliae* powder consists of 1 x 10^9 conidia / ml

Values in parantheses are arcsin percentage values

Table-27 : Effect of neem fruit extract on 3rd instar larvae of *Maruca vitrata* at different time intervals after treatment under laboratory conditions

Dose %	Mortality of *M. vitrata* larva (%)		
	24 hrs	48 hrs	72 hrs
3 %	0.00 (0.00)	0.00 (0.00)	17.50 (24.53)
4 %	0.00 (0.00)	0.00 (0.00)	20.00 (26.56)
5 %	0.00 (0.00)	0.00 (0.00)	30.00 (33.21)
6 %	0.00 (0.00)	0.00 (0.00)	35.00 (36.22)
7 %	0.00 (0.00)	0.00 (0.00)	40.00 (39.23)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
C V			1.195
SE			0.07
C D			3.60

Values in parantheses are arcsin percentage values

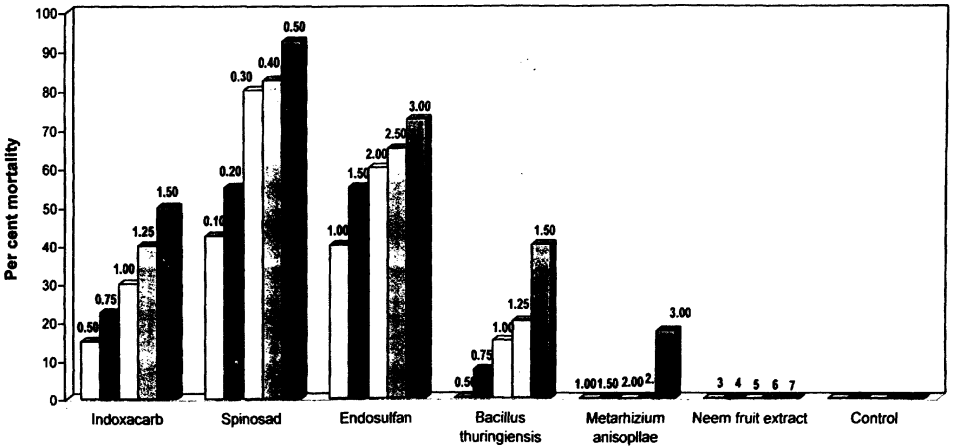


Fig. 36 : Efficacy of selected insecticides against *Maruca vitrata* at 24 hours after treatement

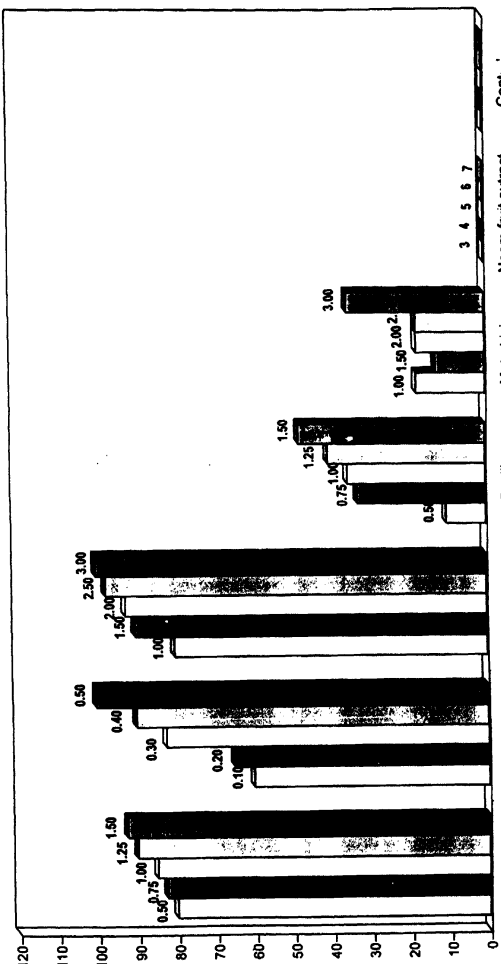


Fig. 37 : Efficacy of selected insecticides against *Maruca vitrata* at 48 hours after treatement

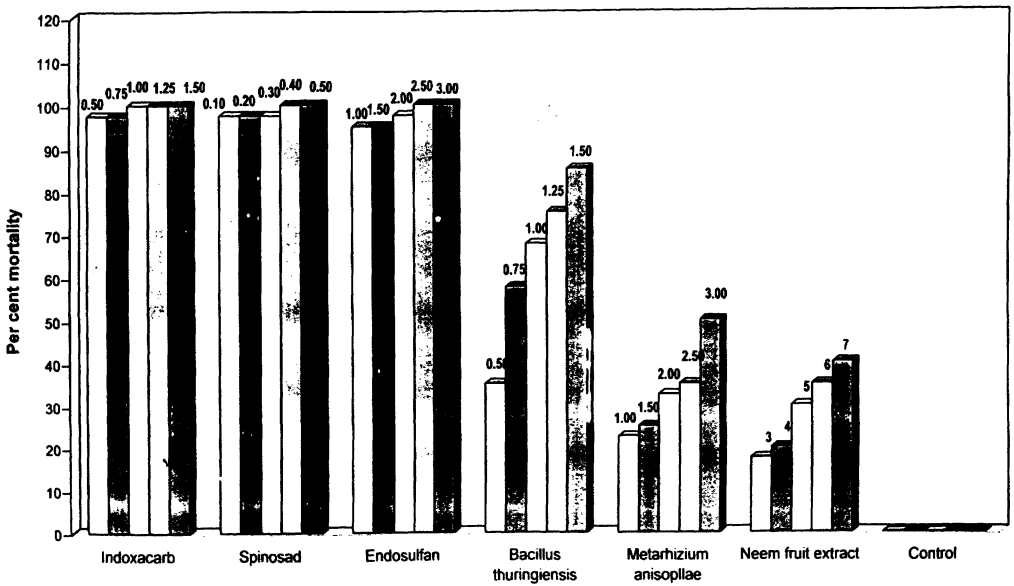


Fig. 38 : Efficacy of selected insecticides against *Maruca vitrata* at 72 hours after treatement

The mortality of larva obtained after 48 hrs of treatment did not show significant difference among the concentrations except with 3.00 g/l which showed 35 per cent mortality.

The pathogenicity of *M.anisopleae* has increased after 72 hrs of treatment and showed 32.50 per cent mortality at the recommended dose (2.00 g/ml) and was not significantly different from the other concentrations. The mortality was 50 per cent with the highest concentration (3.00 g/l). No mortality of larvae was observed after 72 hrs after treatment. No mortality of larvae was observed in control (Table.26).

4.3.6 Efficacy of neem Fruit Extract (NFE) against *M. vitrata*

Neem fruit extract did not cause the mortality of larva upto 2 days whereas after 72 hrs of treatment it resulted in 30 per cent mortality at the recommended dose (5 %) which was on par (35 %) with the next higher concentration (6 %). The lowest concentration (3 %) recorded the least mortality (17.5 %) which was on par (20 %) with 4 % concentration. Maximum mortality of 40 % was obtained with 6 per cent concentration. There was no mortality of larvae after 72 hrs of treatment. No mortality of larvae was observed in control (Table 27).

CHAPTER – V

DISCUSSION

The spotted pod borer *Maruca vitrata* became a serious pest in recent years damaging the reproductive parts of legumes by feeding from inside a webbed mass of leaves, buds and pods causing maximum reduction in grain yield. It is also a serious obstacle for introducing pigeonpea into new areas where humidity is very high and its control becomes very difficult because of its typical feeding habit, which protects it from adverse conditions and natural enemies and sprays. Therefore it is important to have a critical look at the basic information on resistance screening studies and rational use of insecticides for integrated management of this insect. Hence the present studies were conducted to screen some of the short duration pigeonpea genotypes in the field as well as under greenhouse and laboratory conditions. The pod damage and development of the insect were correlated with the physico-chemical characters of pigeonpea genotypes. Some of the ecofriendly and new molecules of insecticides were tested against *Maruca* under laboratory conditions. The results obtained are discussed in detail in the present chapter with the available literature.

5.1 VARIETAL SCREENING STUDIES

For varietal screening studies six selected short duration pigeonpea genotypes (ICPL 98001, ICPL 98002, ICPL 98003, ICPL 98008, ICPL 98012 and ICPL 88034) were tested in the field as well as under greenhouse and laboratory conditions. The performance of the genotypes was assessed based on the pod damage in the field and growth and development of the insect in greenhouse as well as under laboratory conditions.

5.1.1 Field screening studies

The results obtained from the field screening studies revealed (Table 3) that lowest pod damage was recorded in ICPL 98003 and ICPL 98008 (5.80 and 6.77 per cent respectively) compared to the highest pod damage in ICPL 88034 (68.00%). Based on the per cent pod damage the genotypes were given the resistance rating 1 to 5 as suggested by Jackai (1982). Based on the damage score the genotypes *viz.*, ICPL 98003 and ICPL 98008 were categorized as highly resistant, while ICPL 98012 as the moderately resistant genotype. The genotypes ICPL 98001 and ICPL 98002 were grouped under intermediate type. The susceptible genotype was ICPL 88034. The results are in conformity with the findings of Anitha (2005) who reported that the pigeonpea genotype ICPL 98008 with less pod damage and high grain

yield with a unit slope and minimum residual mean square values indicated the stability reaction to pigeonpea pod borer *Helicoverpa armigera* .

Infestation and damage by *M.vitrata* is influenced by plant architecture. Canopy structure and pod position together or independently exert a profound effect on pigeonpea resistance to the pod borer. The resistance of ICPL 98003 and ICPL 98008 could be attributed to the morphological and biochemical parameters of the test genotypes. Among the morphological parameters, the podding habit which was present above the foliage and significantly more pod wall thickness (3.42 mm) and highest density and length of trichomes present on leaves and pods might have contributed to the less preference of ICPL 98003 and ICPL 98008 by *Maruca* (Table 8). The genotype ICPL 88034 with longest pods (7.00 cm) held below the foliage, lowest pod wall thickness (1.27 cm) and short and less number of trichomes on leaves (2.90 cm) showed maximum pod damage (68.00 %) and was considered as susceptible genotype .

Simple correlation and linear regression analysis studies made between per cent pod damage and various physical parameters (Table 11, Fig 2-12), showed a significant negative correlation of pod damage with pod wall thickness, trichome length on leaves and pods and trichome density on leaves.

The results are in conformity with the findings of Singh (1978) who reported that resistance of TVu 946 and TVu 557 cowpea genotypes is due to long peduncles and pods held over the plant canopy. According to Saxena *et al.* (1998) determinate pigeonpeas with clustered inflorescence were more susceptible than the indeterminate type. Tayo (1988) reported that pod size plays an important role in the susceptibility of cowpea to *M. vitrata.* The big pods of VITA-1 provided large surface for larval infestation and sufficient nutrition for larval growth.

In the present study the length and density of trichomes were more in the resistant genotypes as observed by Jackai and Oghiakhe (1989) who demonstrated that the trichomes and phytochemicals were responsible for resistance in wild cowpea TVNu-72 and TVNu-73 to *M.vitrata* compared to the susceptible variety IT 84 E-124. They reported that the length of trichomes were important in contributing resistance. Oghiakhe (1991b) observed the adverse effects of pubescence in wild and cultivated cowpeas on oviposition, mobility, food consumption and utilization by *M. vitrata.* According to Oghiakhe *et al.*, 1992, the cowpea cultivars IT-82D-716 (susceptible), MRV2-84F (moderately resistant) and TVu-946 (resistant) showed variation in trichome length and density on different plant parts. Oghiakhe *et al.* (1992 C) and Peter (1995) observed significant negative correlations between trichome density and pod borer damage.

In the present study pigeonpea genotypes with varying degree of susceptibility to spotted pod borer differed significantly in respect of their biochemical parameters (Table 10). The sugars and proteins observed in the various parts of resistant pigeonpea genotypes were comparatively less than those observed in susceptible and moderately resistant genotypes whereas the phenol content was significantly more in the resistant genotypes. Simple correlation and linear regression studies (Tables 11,12) showed significant positive correlation of pod damage with sugars in leaf and proteins in leaf, flowers and pods. There was significant negative correlation between pod damage and phenols in different parts of the plant. In the present study high sugars & proteins as recorded in ICPL 88034 genotype might have acted as phagostimulants resulting in higher damage. The results are in agreement with the findings of Murkute *et al.* (1993) who reported higher contents of proteins and total sugars in pods of pigeonpea cultivars susceptible to pod borer and higher activity of polyphenol oxidase in pod borer resistant varieties. Highly significant and negative correlation was also reported between pest incidence and total polyphenols (Mohan *et al.*, 1987 and Hahn *et al.*, 1981).

Greenhouse studies

Screening under field conditions is often difficult due to lack of uniform infestation or low levels of infestation. Because of the staggered

flowering of pigeonpea cultivars and variation in pod borer population density over time, lines flowering at the beginning and end of the cropping season may escape insect damage while those flowering in mid season are exposed to heavy infestation. Thus it becomes difficult to select lines with reliable resistance under field conditions unless the material is tested over several seasons and locations. This problem can be avoided through artificial infestation of the test plants under greenhouse conditions (Sharma *et al.*, 1999). In the present study screening of pigeonpea genotypes was done under greenhouse conditions using cage technique for resistance to the spotted pod borer using uniform insect pressure at the flowering stage. The results (Table 4) revealed that the genotype ICPL 88034 recorded significantly highest pod damage resulting in lower yields (1.52 g/ plant) and highest larval weight (70.20 mg). The genotypes ICPL 98003 and ICPL 98008 recorded significantly low pod damage and less larval weight and higher yields than the other genotypes. Thus the greenhouse experiment data confirmed the results obtained from the field.

The resistance of ICPL 98003 and ICPL 98008 could be attributed to many factors. Among them plant architecture and biochemical factors might have played a significant role.

Maruca larvae prefer hidden and shaded places for feeding. In the present study the highly resistant pigeonpea genotypes *viz.*, ICPL 98003

and ICPL 98008 hold the pods above the foliage and also the time required to complete flowering and pod maturity in the above genotypes was also comparatively short. These factors might have resulted in less preference of the genotypes for feeding and less weight gain by the larvae. The results are in conformity with the finding of Singh (1978) and Oghiakhe *et al.* (1991) who showed significantly greater damage of pod borer in cowpea with pods held within the canopy.

Pubescence has been reported to interfere with oviposition, (attachment of eggs to plant surfaces), feeding and ingestion by many insects (Stephens and Lee 1961, Gallun *et al.*, 1973, Ramaswamy, 1988, Jackai and Oghiakhe 1989). In the present study trichome cover on individual cultivars varied in trichome length and density. Significantly longer and higher trichome density was observed in ICPL 98003 and 98008 when compared to the susceptible genotype ICPL 88034. Chiang and Singh, 1988 found a negative and significant correlation between trichome length and density and pod damage of cowpea pods and stated that higher density of trichomes interfere with larval contact. The resistance could also be attributed to the long trichomes which can sufficiently impale larvae of *M. vitrata* to cause mortality and also impede movement (Oghiakhe, unpublished data). In many crops, trichome density is negatively correlated with insect response to feeding as well as larval nutrition. This is also expected to increase exposure time to parasites, predators and adverse environmental factors, there by

maximizing trichome efficiency and consequently raising action threshold levels. In the present study less larval weight found in resistant genotypes could be attributed to more trichome density and length which might have inhibited the larval mobility and food consumption.

Protein content recorded in the pigeonpea genotypes showed significant positive correlation with larval weight gain and pod damage and negative correlation with grain yield whereas the trend was reverse with phenols which showed significant negative correlation with larval weight gain and pod damage and positive correlation with grain yield. Sugars did not show any significant effect on larval weight gain and pod damage (Table 13). Oghiakhe *et al.*, 1993a reported that neither sugars nor phenols seems involved in the resistance of TVNu 72 cowpea variety to *M. vitrata*. In the present study lower concentration of proteins and higher concentration of phenols found in ICPL 98003 and 98008 might have made the genotypes less nutritionally suitable for *Maruca* development resulting in less pod damage and higher grain yields.

Sucrose has been reported to be the strongest feeding stimulant to insects feeding on the plant (Ishikawa *et al.*, 1969). But in the present study no significant correlation was observed between sugars and larval weight and pod damage. It is possible that the phagostimulation effect of sucrose on *M.vitrata* could be masked by the complete mixture of chemicals found in the various parts of plants (Reese,1979).

Laboratory studies

Laboratory studies conducted with *M.vitrata* on the flowers of six pigeonpea genotypes showed variation in the growth and development. The larvae reared on the susceptible genotype ICPL 88034 consumed maximum quantity of food (77.00 mg), excreted more faecal matter (28.00 mg) and gained more larval (64.80 mg) and pupal weights (48.30 mg) and exhibited highest growth rate (276.47%). The larvae reared on one of the highly resistant genotype ICPL 98003 consumed more food (43.00 mg) than the other highly resistant genotype ICPL 98008 (38.00 mg), but showed significantly lowest larval (31.10 mg) and pupal weights (11.30 mg) and recorded lowest growth rate (112. 45 %) than in ICPL 98008 in which increase in the larval and pupal weights and growth rate (33.00 mg, 20.00 mg and 136.79 % respectively) were higher than in ICPL 98003. This could be attributed to the less conversion of ingested (44.98 mg) and digested food (67.50 mg) into body matter and high excretion (23.30 mg) of faecal matter in ICPL 98003 which had resulted in lowest growth rate. The larva reared on the moderately resistant genotype ICPL 98012 also consumed less food (43.00 mg) excreted more faeces (22.50 mg) and showed less consumption index (1.5) and less larval (32.79 mg) and pupal weights (31.50 mg) and showed lowest growth rate (116.38 %). The two genotypes ICPL 98001 and ICPL 98002 which were categorized as intermediate between resistant and susceptible genotypes

showed high efficiency of conversion of ingested and digested food into body matter resulting in high growth rate of larvae than those reared on resistant and moderately resistant genotypes.

Simple correlation and linear regression analysis studies undertaken between chemical constituents of pigeonpea genotypes and growth and development of *M. vitrata* larvae (Tabel 18,19,20 and 21) revealed postive and significant effect of proteins on larval weight gain, per cent pupation and growth rate while the phenols showed negative and significant relation with the above factors. Based on the above findings it can be stated that the biochemical constituents like protein and phenol contents of different pigeonpea genotypes may influence the growth and development of *M.vitrata* larvae.

Sharma *et al.* (1999) observed significant differences in the consumption and utilization of flowers by the 3rd instar larvae of *M. vitrata.* He found that the larvae reared on ICPL 84023 had lower larval and pupal mass than those reared on ICPL 90036-M1-2. He further stated that fecundity was low when the larvae were reared on the pods of *Maruca* resistant cultivar MPG 537-M1-M5.

According to Jackai (1991) *M. vitrata* larvae surviving on pods of resistant cowpea variety TVNu 72 were smaller, produced smaller pupa and lower percentage pupation compared with other test varieties.

Macfoy & Dabrowski (1984) found higher concentration of phenols in the stems of *Maruca* resistant cowpea variety TVu 946 than in susceptible varieties.

EFFICACY OF SELECTED INSECTICIDES AGAINST *Maruca vitrata*

The spotted pod borer (*Maruca vitrata*) often causes serious threat to the cultivation of early pigeonpeas. Considerable number of insecticides have been tested and few of them were found effective against *Maruca* (Saxena *et al.*, 1998 and Sahoo and Senapathi, 2000). But repeated use of these chemicals result in development of resistance to insecticides. Use of new chemical molecules with higher insecticide property, lower mammalian toxicity and lower dosage application fits very well in the present day integrated pest management (IPM) concept. Now a days attempts are also being focused on the use of safer chemicals like plant products and microbial pesticides to reduce the toxic effect of chemicals on non target organisms and prevent the environmental pollution. Hence in the present study some promising newer insecticides and biopesticides were tested against *M. vitrata* larvae and the results obtained from the study are discussed here under.

The efficacy of six selected insecticides comprising two new insecticides (indoxacarb, spinosad), one conventional insecticide

(endosulfan) two biopesticides (*M. anisopliae* and *B.thuringiensis*) and one botanical insecticide (NFE) against 3rd instar larva (Table 2) showed the supremacy of two newer insecticides *viz*., indoxacarb and spinosad over the other tratments. The conventional insecticide endosulfan was also equally effective in bringing the mortality of *Maruca* larvae. Though indoxacarb resulted in less mortality (50 %) at 24 hrs after treatment even with higher concentration, but showed maximum mortality (80%) at 48 hrs after treatment with lower concentrations (0.5 ml/l). Spinosad caused more than 50% mortality at recommended dose (0.3 ml/l) at 24 hrs after treatment.

Because of its very favourable mammalian toxicity and environmental profiles, spinosad has already been registered by EPs for use against lepidopteran pests on cotton (Graves *et al.*, 1999).

Indoxacarb is an oxadiazine group of reduced risk broad spectrum stomach poison with little contact action which causes paralysis and death with in 4-48 hours. Thus the two insecticides spinosad and indoxacarb not only act as effective larvicides but also found to have moderate ovicidal action (Rao *et al.*, 2001) and hence can be safely incorporated in the IPM programme of *M. vitrata.*

The results are in agreement with the findings of Suhas Yelshetty *et al.* (1999) and Bheemanna and Patel (1999) who reported the supremacy of

indoxacarb over other pesticides against *H. armigera* in pigeonpea and cotton respectively. Khalid Ahmed *et al.* (2001) observed highest mortality of *S.litura* eggs with indoxacarb (86.66%), followed by spinosad (73.33%) under laboratory conditions. Gopalaswamy *et al.*, (2000) found spinosad and indoxacarb as equally promising for the control of pink boll worms on par with commonly used quinalphos and cypermethrin. According to Dey and Somchoudhury (2001) spinosad provided effective control of all the lepidopteron pests at a dose level of 15 – 25 g ai/ha and showed very little adverse effect on the important parasitoids of diamond back moth. Based on the present studies and the available literature pertaining to the above two chemicals it is well evident that these two chemicals can serve as one of the most effective tools in IPM of *M. vitrata.*

The commonly used conventional insecticide endosulfan which was tested against *M. vitrata* in the present study was also equally effective and showed higher mortality at 48 hrs after treatment with all the concentrations. Considerable advantage in grain yield due to effective control of *Maruca* in short duration pigeonpea through the use of endosulfan was reported by Samalo & Patnaik (1986) and Makar *et al.* (1994). Minja *et al.*, (2000) reported that spraying the short duration pigeonpea genotypes with endosulfan resulted in good control of pod borers. Though endosulfan was highly effective in controlling the pest in the present study it is known to effect some of the natural

enemies of the insect pests (Wiktelius *et al.*, 1999) and there are reports of *H. armigera* resistance to pyrethroids and endosulfan in India (Lateef 1991). Hence it is advisable to alternate the conventional pesticides with newer chemicals not only between seasons but also reasonably between two or three sprays with in the season to minimize the tendency of pests developing resistance to a particular chemical. Among the biopesticides used in the present study *Bt* was found superior over *M. anisopliae*. The mortality of the larvae was slow up to 48 hours after treatment and maximum mortality (75 & 85%) was observed with higher concentrations (1.25 and 1.5 g/lt respectively) after 72 hours of treatment and was not as effective as the newer and conventional insecticides used in the present study.

The present study also supports the findings of Rahman (1988) who stated that *Bt* was inferior to chemical insecticides against *H. armigera* on cotton. The results are however in variance with those of Purohit and Deshpande (1991) who obtained 90 per cent mortality of *H. armigera* at 96 hours of post treatment with 2 per cent concentration of *B.t* in the laboratory. The biopesticides act slowly and have to be ingested by the insect to become toxic.

Another biopesticide *M.anisopliae* was less effective than novel and conventional insecticides and did not cause the mortality at 24 hours

after treatment and the mortality was very low (less than 50%) even at 48 and 72 hrs after treatment except at higher concentration (3.00 g/lt) which resulted in 50 per cent mortality.

The results are in contrary to the findings of Kulat *et al.*, 2003 who found the highest larval mortality (97.50%) of 2nd instar larvae of *H. armigera* with 2.28 x 10^{10} conidia/ml of *M. anisopliae*. Gopalakrishnan and Narayanan (1989) also reported the pathogenicity of *M. anisopliae* to larval instars, pre pupa and pupae of *H. armigera* at 1.8 x 10^{9} conidia /ml. Ekesi *et al.*, 2002 observed the highest pathogenisity of *M. anisopliae* to eggs (89 to 100 per cent mortality) and larvae of *M. vitrata* with 1 x 10^{8} conidia / ml in the laboratory.

Less pathogencity of the fungus against the test insect in the present study could be attributed to the method of application of fungus on the insect. The germination of fungal spores and subsequent mycelial growth on the insect would take place if it comes in direct contact with the larval body. But the pest used in the present study is a hidden pest and the fungal suspension was applied on the flower bouque in which the pest was hiding. Hence, there is less chance of direct contact of the fungus with the insect body and causing subsequent infection. The previous studies were conducted by applying the fungus directly on the insect body which might have resulted in effective control.

The botanical insecticides neem fruit extract was found least effective. There was no mortality of the treated larva even after 24 and 48 hours of treatment. The mortality was also less (40%) even at higher concentration after 72 hrs of treatment showing its inefficacy against *M. vitrata*. The results are in accordance with the findings of Minja *et al.* (2000) who indicated that neem extract and *B.thuringiensis* were not as effective as the synthetic insecticides against pod borers on pulses.

Based on the above findings it can be concluded that ICPL 98003 and ICPL 98008 are the promising genotypes which showed less pod damage and were least prefered for growth and development, while ICPL 88034, a susceptible genotype recorded more pod damage and showed highest growth and development of larva. Several plant characteristics such as pod wall thickness, trichome length and density and chemical constituents like sugars, proteins and phenols contributed to the preference of genotypes to *Maruca*. The studies on the biochemical and biophysical characters need to be accelerated to identify the various components of resistance for use as markers in screening programmes and to assist breeders in determining the best parentage in making crosses. Among the insecticides tested against *M.vitrata* the newer and ecofriendly insecticides, spinosad and indoxacarb were highly effective. Though the conventional insecticide endosulfan tested in the present study was equally effective and on par with newer chemicals, repeated use of this chemical may be minimised

by selecting the new generation chemicals like indoxacarb and spinosad in view of the favourable mammalian toxicity, ovicidal action and safety to natural enemies. Since *M.vitrata* is a hidden pest and is very difficult to control once it enters the web and feed inside, future insecticide spraying studies should focus on economic thresholds and timing of application.

CHAPTER – VI

SUMMARY

The present investigations were carried out to evaluate selected short duration pigeonpea genotypes *viz.*, ICPL 98001, ICPL 98002, ICPL 98003, ICPL 98008, ICPL 98012 and ICPL 88034 in the field, greenhouse and laboratory conditions against *M.vitrata* at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh during 2004-2005 crop season. The relative efficacy of some newer and ecofriendly insecticides *viz.*, indoxacarb, spinosad, endosulfan, *Metarhizium anisopliae*, *Bacillus thuringiensis* and neem fruit extract were tested against 3rd instar larvae of *M.vitrata* under laboratory conditions.

The varietial screening studies conducted in the field showed lowest pod damage in ICPL 98003 (5.8%) and ICPL 98008 (6.8%) and highest pod damage in ICPL 88034 (68%). Based on the pod damage the genotypes were given the resistance rating 1-5. The genotypes ICPL 98003 and ICPL 98008 which recorded the damage score of 0.25 and 0.35 were categorized as highly resistant and ICPL 98012 (1.24) was found to be moderately resistant, while ICPL 98001 and ICPL 98002 with a resistance rating of 2.40 and 2.55 were intermediate between resistant and susceptible. ICPL 88034 was rated as susceptible genotype and recorded 3.45 damage score.

Varietal preference studies conducted in the greenhouse conformed the results obtained from the field conditions and showed lowest pod damage in highly resistant genotypes ICPL 98003 (17.40%) and ICPL 98008 (21.74%) and highest pod damage in susceptible genotype ICPL 88034 (32.42%). The highly resistant genotypes recorded less larval weight gain when compared to the susceptible and intermediate genotypes. Significantly lowest grain yield was recorded in the susceptible genotype ICPL 88034 (1.52 g/plant) when compared to the highly resistant genotype ICPL 98003 (3.34 g/plant).

Maruca larvae reared on flowers of six pigeonpea genotypes under laboratory conditions showed variation in their growth and development. The mass of food consumed by the larvae was highest in the susceptible genotype ICPL 88034 (77.00 mg) while it was lowest on the highly resistant genotype ICPL 98008 (38.00 mg). The increase in larval and pupal weight and growth rate were highest on ICPL 88034. The larvae reared on the highly resistant genotypes showed less larval and pupal weights. Similarly the larvae reared on highly resistant and moderately resistant genotypes showed less approximate digestability (AD) and consumption index (CI) than those reared on the susceptible genotype.

The correlation and linear regression studies carried out between physico-chemical parameters of the pigeonpea genotypes with pod damage and growth and development of larvae revealed that pod wall

thickness, trichome length & density had negative and significant relation with pod damage and larval weight gain. The chemical constituents *viz.*, proteins and sugars showed positive significant correlation with pod damage and larval weight gain and phenols showed negative correlation with pod damage and larval weight gain.

The laboratory studies conducted on the relative efficacy of selected newer and ecofriendly insecticides against 3rd instar larvae of *M. vitrata* showed that the newer insecticides *viz.*, indoxacarb and spinosad were highly effective against *M. vitrata* at recommended dose and the conventional insecticide also showed higher efficacy on par with the newer insecticides. The two biopesticides *viz.*, *B. thuringiensis* and *M. anisopliae* were moderately effective and the botanical pesticide, neem fruit extract was found ineffective against *M. vitrata*.

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* Original not seen

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