BIOPHYSICAL AND BIOCHEMICAL EVALUATION OF COWPEA GERMPLASM AGAINST MAJOR INSECT PESTS

M.Sc. (Ag)

by

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DEPARTMENT OF ENTOMOLOGY

COLLEGE OF AGRICULTURE,

INDIRA GANDHI KRISHI VISHWAVIDYALAYA

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BIOPHYSICAL AND BIOCHEMICAL EVALUATION OF COWPEA GERMPLASM AGAINST MAJOR INSECT PESTS

Thesis

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By

MAYA SHREE MAHIPAL

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CERTIFICATE - I

This is to certify that the thesis entitled **"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** submitted in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Maya Shree Mahipal** under my/our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

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

Date: 18/07/2016

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(Shri Gajendra Chandrakar)

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	**(Dr. Dhananjay Sharma)**	18/07/2016
Member	**(Dr. Dharmendra Khokhar)**	18.07.16
Member	**(Dr. Ravi R. Saxena)**	18/7/16

CERTIFICATE – II

This is to certify that the thesis entitled **"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** submitted by **Maya Shree Mahipal** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) in the Department of Entomology has been approved by the external examiner and Student's Advisory Committee after oral examination.

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Approved/Not approved

Director of Instructions _____

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Msmahipal 18/07/2016

Maya Shree Mahipal

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Date : 18/07/2016

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LIST OF SYMBOLS/ NOTATION

Symbols	Description
%	Per Cent
@	At The Rate
°C	Degree Celcius

LIST OF ABBREVATIONS

Abbrevation	Description
&	And Others/Co-Workers
cm	Centimeter
DAS	Days after sowing
et al	And Others/Co-Workers
Fig.	Figure
g	Gram
ha	Hectare
hrs	Hours
i.e.	That Is
Kg	Kilogram
m	Meter
M ha	Million Hectare
mm	Millimeter
Mt	Million Ton
No.	Number
NS	Non Significant
P.I.	Pod Infestation
Q	Quintal
R	Correlation Coefficient
Rs.	Rupees
SMW	Standard Meteorological Week
Viz	Namely
WAS	Week after sowing

THESIS ABSTRACT

a) Title of the Thesis: Biophysical and biochemical evaluation of cowpea germplasm against major insect pests.

b) Full Name of the Student: Maya Shree Mahipal

c) Major Subject: Entomology

d) Name and Address of the: Shri Gajendra Chandrakar,
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e) Degree to be Awarded: M.Sc. (Ag)

Signature of the Student

Signature of Major Advisor

Date: 18/07/2016

Signature of Head of the Department

ABSTRACT

Investigation on **"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** was conducted at Horticulture experimental field, department of Entomology and laboratory works were conducted in department of Crop Physiology, Agricultural Biochemistry and Herbal Science of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) in Kharif, 2015.

The study revealed that the major insect pest viz., spotted pod borer, flower thrips, pod sucking bug and green stink bug were attacking in cowpea germplasm. The incidence of pod sucking bug, green stink bug and flower thrips started from third week after transplanting, further increased and recorded the peak activity of 9.0 bugs per plant and 12.3 bugs per plant during second week of November, whereas the peak activity of 4.3 thrips per plant was observed during first week of October. The cowpea spotted pod borer infestation was first appeared during fifth week of September, increased gradually with peak pod infestation of 19.7 per cent during third week of October.

The population of lady bird beetle and spider coincided with the appearance of host insects throughout the crop season with peak population of 1.5 beetles per plant during fourth week of November and 1.6 spiders per plant during fifth week of October.

The results of screening the cowpea germplasm against tested insect pest showed that among the thirteen germplasm, 2015/COPBVAR-2, 2015/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-2, 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, KASHI KANCHAN, Lola and Arka Garima were least preferred by insect pest while 2015/ COPBVAR-5 found moderately resistance for the insect pest.

The population of flower thrips and pod sucking bug was positively and non significant correlated with maximum and minimum temperature while negatively correlated with maximum and minimum relative humidity, rainfall and sunshine hours. The cowpea spotted pod borer infestation showed positive and non significant correlation with maximum and minimum temperature, rainfall and sunshine hours, maximum and minimum relative humidity.

The per cent pod borer infestation showed positive correlations with plant height at 70 DAS. The positive correlation was found between per cent pod borer infestation and pod length ($r = 0.849$) and pod weight ($r = 0.628$), whereas, negative correlation was found with number of pods per plant ($r = – 0.715$) and pod width ($r = – 0.153$). A strong negative correlation between the cowpea spotted pod borer infestation and total phenol content ($r = – 0.794$), while strong positive correlation with total sugar content ($r = 0.851$) was noticed on cowpea germplasm.

शोध सारांश

शोध शीर्षक	–	प्रमुख कीटों के विरूद्ध बरबट्टी जर्मप्लाज्म की जैव भौतिक एवं जैव रासायनिक मूल्यांकन
छात्रा का नाम	–	मायाश्री महिपाल
मुख्य विषय	–	कीट–विज्ञान
मुख्य सलाहकार का नाम व पूरा पता	–	श्री गजेन्द्र चंद्राकर (वैज्ञानिक) कीट–विज्ञान विभाग कृषि महाविद्यालय, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.)
उपाधि का नाम	–	एम.एस.सी. (कृषि)

मुख्य सलाहकार के हस्ताक्षर

दिनांक 18/07/2016

छात्रा का हस्ताक्षर

विभागाध्यक्ष के हस्ताक्षर

शोध सारांश

"प्रमुख कीटों के विरूद्ध बरबट्टी जर्मप्लाज्म में जैव भौतिक एवं जैव रसायनिक मूल्यांकन" हेतु खरीफ (2015) में इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) के उद्यानिकी प्रायोगिक प्रक्षेत्र, कीट शास्त्र विभाग, पादप कार्यिकी, कृषि जैव रसायन एवं हर्बल विभाग में शोध आयोजित किए गए।

शोध से यह अवगत हुआ कि बरबट्टी जर्मप्लाज्म में प्रमुख कीट जैसे चित्तीदार फली भेदक, फूल थ्रीप्स, फली चूषक बग और हरे रंग वाली का प्रकोप था फली चूषक बग, हरे रंग वाली बग और फूल थ्रीप्स का प्रकोप रोपाई के तीसरे सप्ताह से प्रारम्भ हो चुकी थी, इसकी संख्या आगे बढ़कर 9.0 कीड़े

प्रति पौधे फली चूसक बग के एवं नंवबर के दूसरे सप्ताह के दौरान 12.3 कीड़े प्रति पौधे शीर्ष गतिविधि दर्ज की गई, जबकि 4.3 कीड़ों के शीर्ष गतिविधि प्रति पौधे अक्टूबर के पहले सप्ताह के दौरान देखे गए।

मित्र कीटों में मकड़ी की संख्या अक्टूबर के पांचवे सप्ताह के दौरान प्रति पौधे 1.6 मकड़ी और नवंबर के चौथे सप्ताह के दौरान लेडी बर्ड बीटल प्रति पौधे 1.5 बीटल के शीर्ष आबादी के साथ फसल के मौसम में पोषक कीड़ों की उपस्थिति के साथ हुई।

बरबट्टी जर्मप्लाज्म कीट परीक्षण के लिए मूल्यांकन करने पर नतीजे बताते है कि तेरह जर्मप्लाज्म के बीच – 10 (दस) जर्मप्लाज्म (2015/COPBVAR-2, 2015/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-2, 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, काशी कंचन**,** लोला एवं अर्का गरीमां में कम से कम कीट पाया गया था जबकि 2015/COPBVAR –5 में कीट का प्रकोप देखा गया।

न्यून्तम तापमान में फूल थ्रिप्स एवं फली चूषक बग की संख्या सकरात्मक और अधिकत्म गैर महत्वपूर्ण सहसंबद्ध था। जबकि अधिकत्मक और न्यून्तम सापेक्ष आर्द्रता, वर्षा और सूर्य प्रकाश के साथ नकारात्मक संबंध था।

बरबट्टी चित्तीदार फली भेदक का प्रकोप अधिकतम तापमान न्यून्तम तापमान, अधिकत्मक सापेक्ष आर्द्रता, न्यून्तम आर्दता, वर्षा एवं सूर्य प्रकाश के साथ नकारात्मक एवं गैर महत्वपूर्ण सह संबंध था। फली भेदक प्रतिषत प्रकोप बुवाई के 40 दिन बाद पौधे की उंचाई के साथ सकारात्मक सहसंबंध दिखाया।

फली की लंबाई (r=0.849) और फली का वजन (r=0.628) के साथ सकारात्मक संबंध था। जबकि फली संख्या (r=0.715) और फली चौड़ाई (r=0.153) के साथ नकारात्मक एवं महत्वपूर्ण संबंध पाया गया। बरबट्टी चित्तीदार फली भेदक का प्रकोप और कुल फिनाल (r=0.794) का मजबूत नकारात्मक सहसंबंध देखा गया जबकि कुल कार्बोहाइड्रेट (r=0.851) का मजबूत सकारात्मक संबंध बरबट्टी जर्मप्लाज्म में पाया गया।

CHAPTER-I
INTRODUCTION

The cowpea (*Vigna unguiculata* L. Walp) is considered a grain legume or pulse (Uwaegbute, 1991). Cowpea is a tropical, annual herbaceous legume, which belongs to the family Papilionaceae (Fabaceae), order Leguminosae and genus *Vigna*. The genus *Vigna* consists of over one hundred different species widely found in the tropical and sub-tropical regions and has great morphological and ecological diversity. It is believed to have originated in Africa and Asia (reviewed by Taiwo, 1998), and is widely cultivated in the tropics (Chavan *et al.* 1989). Other names commonly used for cowpeas include catjang, blackeyed bean or chinapea (reviewed by Taiwo, 1998).

Cowpea *V. unguiculata* can grow up to 80cm and up to 2m for climbing cultivars. It has a well developed root system. Germination is epigeal with the first pair of true leaves being simple and opposite and subsequent leaves being trifoliate with oval leaflets (6-15cm long and 4-11cm broad) and alternate. The papillonaceous flowers are born on racemose inflorescences at the ends of peduncles that arise from leaf axils and can be white, yellowish, pale blue or violet. Peduncles are stout and grooved and usually much longer than the leaves (2 to 20 cm long). For each inflorescence, flowers are sequentially produced in alternating pairs on thickened nodes at the tip with cushion-like extra-floral nectarines between each pair of flowers. The flower is large (standard is 2-3cm in diameter), with a straight keel, diadelphous stamens (one free and nine fused), a sessile ovary with many ovules, and a style that is bearded along the inside and ends in an oblique stigma. Pods occur in pairs forming a V, mostly pending and vertical but they can be erect. They are cylindrical, 2 to 6cm long and 3 to 12mm broad and contain 8 to 20 seeds. Seeds can be white, pink brown or black (Heuzé et al, 2013)

As a legume, cowpeas are rich and low-cost sources of dietary proteins and nutrients (Egounlety & Aworh, 2003) and they form part of a staple diet in most African and Asian countries (Aykroyd & Doughty, 1964). The cowpea seeds are made up of cotyledons, germ and a seed coat with testa and hilum (Chavan *et al*.,

1989). The seeds may vary in colour, shape and size. The seed coat colour ranges from white, purple to black. The seed composition, predominantly the proteins and starch varies considerably according to cultivar and seed origin (reviewed by Taiwo, 1998).

Young leaves, pods and beans are used as fresh vegetables. The tender leaves are also used as a vegetable (Kayumbo, 1978). All parts of the plant used for food are nutritious, providing protein, vitamins and minerals. The cowpea grain contains an average of 23- 25% protein and 50-67% carbohydrates (Singh *et al*., 1997). It has fat content of 1.3%, fibre content of 1.8% and 8-9% of water. Because of its high protein content, cowpea is extremely valuable where many people cannot afford high protein foods such as meat and fish (IITA, 2007). The crop is also important in soil fertility improvement, and is reported to fix up to about 70 kg N/ha/year (Palaniappan 1984).

Globally in the year 2003, about 12.4 million hectares of land is used to cultivate cowpeas, with Central and West Africa contributing about 8 million hectares (FAO Statistical Database, 2004). Cowpea is grown worldwide with an estimated cultivation area of about 14.5 million hectares annually and an annual worldwide production of over 4.5 million metric tons (Singh *et al*., 2002). World cowpea production was 3,721,850 Mt during the year 2003, with Africa and Asia contributing 90% and 7.6% respectively (FAO Statistical Database, 2004).

In India cowpea is grown in Rajasthan, Maharashtra, Madhya Pradesh, and Chhattisgarh. In Gujarat, Cowpea is cultivated in about 23,600 ha with an annual production of 19,900 tonnes and on average cowpea occupies area of 6937 hectares with an annual production of 42,432 tonnes (Anonymous, 2003-04). Rajasthan production is highest producing with 49.08 thousand tonnes and then moderate producing state is Maharashtra producing 8.9 thousand tonnes on an average in the years 2008-09 to 2011-12.

Among the several factors responsible for low yields of cowpea, insect pests are major limiting factors. More than 100 species of insects live and feed on cowpea. The most damaging pests of cowpea include those that occur during the flowering and podding stages. These pests include flower thrips, such as *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae), pod borer, *Maruca*

vitrata (Fabricius) (Lepidoptera: Crambidae) and pod suckers such as, *Clavigralla tomentosicollis* (Stål) ,Hemiptera: Coreidae (Adati *et al.*, 2004). The biology of these pests are described by Cardona and Karel (1990) but their relative impact varies with season and location; heteropterans often cause more economic loss than *M. vitrata*, although the latter alone has been reported to cause up to 80% crop losses (Duke, 1981). Though, the natural enemies play an important role in limiting the potential pest population surges, yet their members are not sufficient to manage the pest population below economic injury level (EIL).

According to Adipala *et al.* (2000) among all the insects which are found in cowpea crop, aphids and pod borers are ranked as the most important pests followed by pod sucking bugs, leaf beetles (*Ootheca* sp.) and flower thrips. Karungi *et al.* (2000c), it was established that thrips accounted for the greatest yield reduction (28%), aphids10.4%, legume pod borers 15.2% and pod sucking bugs 13.8%.

Pod borer (*Maruca vitrata)* are most damaging pest during flower bud and also the post flowering stage (Nair, 1986 and Yadav and Yadav, 1983). The deformation or direct damage of floral parts imparts adverse effect on yield. After pod formation the borer scrap and bore into the pod, feeding the seeds inside resulting indirect damage of pods (Shivalingaswamy *et. al.*, 2005). Pod-sucking bugs leave feeding punctures that are not easily detectable but which are responsible for the premature shrivelling of young pods and the occurrence of half-filled seeds in older pods (Singh and Jackai, 1985; Jackai *et al*., 1989). These feeding punctures distinguish the pod shrivelling caused by PSB from that caused by other stresses such as drought and disease.

As in all cropping systems there are a variety of natural enemies feeding/developing on cowpea insect pests. These natural enemies include more than 25 parasitoid species belonging to the families (Jackai and Daoust, 1986; Bottenberg *et al.*, 1998; Adati *et al*., 2008). In addition to parasitoids, generalist predators also feed on cowpea insect pests. These include mites, beetles, ants, bugs and spiders (Bottenberg *et al*., 1998; Adati *et al*., 2008).

The bases of relative infestation in different germplasm of cowpea might be due to varied morphological and biochemical traits of the host plant. Host plant

resistance is itself an excellent pest suppressing method and occurrence of natural enemies result in quality produce without any insecticidal residues in the produce for the safe consumption by the people at present.

Many morphological and biochemical factors are known to be associated with insect resistance in crop plants. It is obvious in many cases that the morphological factors are more important in conferring non-preference and antibiosis. Some biochemical constituents may act as feeding stimuli for insects. Occurrence at lower concentration or total absence of such biochemical leads to insect resistance (Singh, 1983).

A major limiting factor to the utilization of cowpeas as food is the presence of anti-nutritional factors such as trypsin inhibitors, oligosaccharides and phenolic compounds (Chavan, *et al.* 1989). Phenolic compounds (tannins in particular) are an important group of such anti-nutritional factors. They are able to form complexes with food nutrients such as minerals and protein, thus rendering them less soluble or less susceptible to enzymatic degradation and less available for absorption.

For developing effective management practices, it is important to know seasonal occurrence of insect-pests and their natural enemies in a particular region. Therefore, the present study on occurrence of insect-pests infesting cowpea and their natural enemy complex in relation to weather variables were conducted.

Therefore, to determine the response of morphology and biochemical traits of different germplasm of cowpea against their major insect pest and natural enemies were investigated under following objectives:

1. Status of major insect pests and natural enemies on cowpea germplasm.
2. Study of biophysical characteristics influencing the infestation rate of insect pests.
3. Biochemical analysis of plant parts related to resistance against major insect pests on cowpea germplasm.

CHAPTER - II

REVIEW OF LITERATURE

For the sake of convenience and clarity the review of literature for the study entitled **"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** is given under the following sub-heads:

1. Status of major insect pests and natural enemies on cowpea germplasm.
2. Study of biophysical characteristics influencing the infestation rate of insect pests.
3. Biochemical analysis of plant parts related to resistance against major insect pests on cowpea germplasm.

2.1: Status of major insect pests and natural enemies on cowpea germplasm

2.1.1: To study about the status and pest succession on cowpea

Faleiro *et al.* (1986) conducted experiment in field of Delhi, India in 1983-84. He monitored pest complex of cowpea (*Vigna unguiculata*) and the succession of insect pests occurring on cowpea crop. A total of 22 species were recorded on the high-yielding variety V 16, together with 8 species of natural enemies (7 predators and a fungus).

Sarma and Dutta (1996) conducted experiment in India during the summers, adults of *Nezara viridula* appeared on green gram (*Vigna radiata*) during the 3rd or 4th week of April at the pod formation stage. Peak numbers of *N. viridula* coincided with the period of pod maturity. As the crop reached full maturity, pest numbers declined. There was a positive correlation between the minimum temperature and number of *N. viridula*. , thomisid *Thomisus* sp. and the scelionid parasitoid *Trissolcus* sp.

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 was laid on ICPL 90011.

Oparaeke *et al*. (2000) evaluated the efficacy and synergistic activity of extracts mixtures from herbal landraces in reducing pests' numbers on cowpea plants and ensuring high yield of grains in 1999 and 2000 rainy seasons. The

extracts mixed in a ratio 10:10 % (w/w) included: cashew nutshell + garlic bulb; cashew nutshell + African pepper and garlic bulb + chilli pepper. The results indicated that all the herbal extract mixtures reduced the numbers of the tested insect pests (legume flower bud thrips, legume pod borer larvae and pod sucking bugs) and pod damage as well as increased grain yields by 4 - 5 times compared to the untreated control in the two years of investigation.

Alabi *et al*. (2003) screened ten cultivars of cowpea for resistance to flower bud thrips, *Megalurothrips sjostedti*, in replicated field trials. They found in the first season cultivars were conveniently grouped into three, using damage indices and thrips population's size. In the second season, due to the highest thrips population, division into groups was not entirely achievable. Sanzibanili, Moussa local, Sewe and IT90K-277-2 had consistently low damage indices and thrips population numbers; hence they performed better than the resistant control (TVu1509). TV6 3236 also performed well in the two seasons, but with slightly higher damage index and thrips numbers than the cultivars afore mentioned. IT91K-180 and Kpodjiguegue, while supporting a higher number of thrips than the other cultivars, also had larger number of pods, suggesting tolerance as their mechanism of resistance.

Bharathimeena *et al.* (2008) assessed the seasonal incidence of pod sucking bugs infesting vegetable cowpea and their natural enemies. The nymphal and adult population of the pentatomid stink bug, *Nezara viridula*, attained peak values during May 2006 and the first fortnight of April 2006, respectively. The nymphal population of the alydid pod bugs, *Riptortus pedestris* and *Riptortus linearis*, was significantly higher during the first fortnight of May 2006 and the succeeding three fortnights. Adult population of *R. pedestris* and *R. linearis* peaked significantly during the first and second fortnights of June 2006, respectively, when compared to most other periods of the year.

Kumar *et al.* (2009) conducted experiment at Chandra Shekhar Azad University of Agriculture & Technology, Kanpur during *Kharif* season of 2007–2008. Cowpea variety Pusa komal and fourteen genotype of cowpea were evaluated against major pests of cowpea legume pod borer were observed as major pests of cowpea at flower and pod stages of crop growth.

Egho (2010) studied the management of major field insect pests the cowpea aphid, *Aphis craccivora* Koch, legume bud thrips *Megalurothrips sjostedti* Tryb, legume pod borer, *Maruca vitrata* Fab. and pod sucking bugs of cowpea under calendar and monitored sprays of cypermethrin. Influence of insect pest management on yield was also determined. The calendar sprays consisted of 7 days' spray intervals carried out 5 times and 10 days' spray intervals, carried out 4 times. Results indicated that all the cypermethrin treatments effectively controlled *M. sjostedti*, *M. vitrata*, flower bud thrips population and pod sucking bugs when compared to control in the early season. However, there was no significant difference (P>0.05) in calendar and monitored sprays.

Sonune *et al.* (2010) revealed that the incidence of this pest commenced from the 2nd week of August and remained active up to the first week of October. The pest showed one peak of its population with 3.84 larvae per plant at the 4th week of August. Correlation studies indicated that larval population and per cent pod damage by spotted pod borer exhibited a significant negative correlation (r = -0.5540 and r = -0.5556 respectively) with minimum temperature. There was no effect of other abiotic factors on the pest population and pod damage.

African Soil Health Consortium (2015) revealed that bean flower thrips are a major pest of cowpea and other leguminous crops throughout sub-Saharan Africa. The pest feeds on the buds and flowers of the crop, which can cause the flowers to be distorted and fall from the plant, resulting in crop losses. Control of the pest can be achieved through a combination of cultural practices, such as ploughing to destroy pupae, intercropping and crop rotation with maize, planting early, and use of chemical pesticides, including home-made remedies based on black pepper.

Barad *et al.* (2014) conducted experiment at Centre of excellence for Research on Pulses, S. D. Agricultural University, Sardarkrushinagar during *Kharif* 2010. He recorded that the lowest and highest population and pod damage of spotted pod borer among twenty cowpea genotype.

Ezeak *et al*. (2014) evaluated four elite genotypes (IT 97K-499-35, IT 97K-568-18, IT 98K-131- 2 and IT 93K-452 2) emanating from the breeding programme of International Institute of Tropical Agriculture (IITA), Ibadan for

their relative adaptations to a rainy season environment. They took a local variety as a check. The result revealed the presence of genotype x season interaction. Reproductive grain yield and insect damage on the crop differed significantly ($p<0.05$) between genotypes and/or season. Prevalence of pod sucking bugs and thrips were more evident on the late crops than on the early, while the reverse was the case for aphid, *Maruca* and *Ootheca* counts. Bruchid populations were not affected by seasonal variation.

Singh and Singh (2014) monitored eight insects namely jassid, pod bug, leaf miner, whitefly, thrips, legume pod borer, lady bird beetles (predator) and spiders (predator) appeared on cowpea under field experiment at weekly interval during cropping seasons of *zaid*, 2009-10 and 2010-11. The incidence patterns of these insects were almost similar with slight fluctuations during both cropping seasons. The correlation and regression coefficients showed both positive and negative relationships of insect-pests infesting cowpea and their natural enemies with existing weather variables.

Kumar *et al.* (2015) conducted experiments during *Kharif* season of 2007-2008. The pest population was recorded in cowpea field aphids, jassid, thrips and pod borer and its highest population 116.20/15 cm shoots tip, 8.6/compound leaves, 5.87/flower bud and 0.73/flower bud and 1.8/pod, respectively. Abiotic factors influenced the infestation and stabilization of various insect pests in cowpea. The populations of aphids and pod borer influenced positively relative humidity while that of jassid was affected by temperature and sunshine hour.

Sreekanth *et al.* (2015) conducted experiment at Regional Agricultural Research Station, Lam farm, Guntur during 2013-14 on pigeonpea (*Cajanus cajan* (L) Millsp) yielded a good amount of information on the trend of population build up and seasonal abundance of spotted pod borer, *M. vitrata*. The larval population/plant gradually increased from third week of November (47th standard week) and reached peak level (12.6 larvae/plant) at the third week of December (51st standard week), which coincides with the peak flowering stage of the crop. The pest remained active up to last week of January.

Yadav *et al.* (2015) conducted experiment was at Agricultural Research Farm of Banaras Hindu University, Varanasi, Uttar Pradesh, on mung bean the pod

sucking bug was observed in 35th standard week with intensity (0.8/plant) and attained its peak in 38th standard week (6/plant) and had significantly negative correlation with minimum and average temperature and positively with age of crop. The population of spotted pod borer was ranging from 0.2 to 2.4 larvae per plant. The incidence of this pest started in 35 standard week and attended a peak 2.4 larvae/plant during 38 standard week.

Yadav *et al.* (2015) carried out investigation on population dynamics of major insect pests that attack cowpea [*Vigna ungiculata* (L.) Walp.] at Regional Horticultural Research Station, Navsari Agricultural University, Navsari during 2012-13. Spotted pod borer population started from 1st week of November coinciding with the flower initiation and reached to a peak of 2.8 larvae per leaf in 1st week of December. Among various weather parameters, evening relative humidity showed a significantly negative influence.

2.1.2: To study the correlation between different insect pest population and weather parameter

Alghali (1993) experimented to examine the effects of four agro meteorological factors on population fluctuations in legume pod borer, *Monica testulalis* (Geyer) in two cowpea varieties was carried out under field conditions in Ibadan, Nigeria. Three peaks of the pod borer populations were observed on the cowpeas. Significant relationships were obtained between pod borer counts and (a) cumulative rainfall (R^2 = 0.41; P = 0.004) (b) number of rainy days (R^2 = 0.17; P = 0.04) from plant emergence to 50% flowering.

Bharathimeena *et al.* (2008) revealed that the minimum temperature was positively correlated with the population of nymphs of *Riptortus* spp., adult *R. pedestris* and adult *N. viridula*. Preying mantids and spiders were also documented in the cowpea ecosystem.

Patel *et al.* (2010) conducted experiment in Anand, Gujarat, India, during the 2007 summer season, to determine the population dynamics of insect pests of cowpeas in relation to different environmental factors. Incidence of all the major insect pests was recorded at weekly intervals starting from 15 days after germination and continued until harvest. The *Aphis craccivora, Empoasca kerri, Bemisia tabaci, Megaleurothrips* sp., *Acrocercops caerulea* [*Phodoryctis caerulea*]

and *Maruca vitrata* populations were recorded. The effects of temperature, relative humidity, sunshine hours, wind speed and vapour pressure on the pest populations were also determined. Results showed that none of the parameters had a significant effect on the occurrence of leafhoppers, whiteflies, thrips and leafminers, while temperature and sunshine hours exhibited significant negative effects on aphid incidence.

Singh and Singh (2014) monitored eight insects namely jassid, pod bug, leaf miner, whitefly, thrips, legume pod borer, lady bird beetles (predator) and spiders (predator) appeared on cowpea under field experiment at weekly interval during cropping seasons of zaid, 2009-10 and 2010-11. The incidence patterns of these insects were almost similar with slight fluctuations during both cropping seasons. The correlation and regression coefficients showed both positive and negative relationships of insect-pests infesting cowpea and their natural enemies with existing weather variables.

Yadav *et al.* (2015) revealed that the population of thrips appeared in 35^{th} standard week ranging from 0.2–1.2/flower and had positive significant correlation with minimum and average relative humidity. The pod sucking bug was observed in 35^{th} standard week with intensity (0.8/plant) and attained its peak in 38^{th} standard week (6/plant) and had significantly negative correlation with minimum and average temperature and positively with age of crop. The population of spotted pod borer was ranging from 0.2 to 2.4 larvae per plant. The incidence of this pest started in 35 standard week and attended a peak 2.4 larvae/plant during 38 standard week. The correlation of spotted pod with weather factors exhibited significantly negative correlation with minimum and average temperature and highly significant with age of crop. Rests of the weather parameters were non-significantly correlated with the pest population.

Yadav *et al.* (2015) carried investigation on population dynamics of major insect pests that attack cowpea [*Vigna ungiculata* (L.) Walp.] at Regional Horticultural Research Station, Navsari Agricultural University, Navsari during 2012-13. Spotted pod borer population started from 1st week of November coinciding with the flower initiation and reached to a peak of 2.8 larvae per leaf in

1st week of December. Among various weather parameters, evening relative humidity showed a significantly negative influence.

Sreekanth *et al.* (2015) conducted experiment at Regional Agricultural Research Station, Lam farm, Guntur during 2013-14 on pigeonpea (*Cajanus cajan* (L) Millsp) yielded a good amount of information on the trend of population build up and seasonal abundance of spotted pod borer, *M. vitrata*. The larval population/plant gradually increased from third week of November (47th standard week) and reached peak level (12.6 larvae/plant) at the third week of December (51st standard week), which coincides with the peak flowering stage of the crop. The pest remained active up to last week of January. Highly significant correlation was obtained between *M. vitrata* and minimum temperature, mean temperature and wind speed with correlation coefficient (r) being -0.759, -0.815 and -0.838, respectively**.** Moderately significant correlation was obtained between *M. vitrata* and sunshine hours and evening relative humidity (RH-II) with correlation coefficients (r) being 0.656 and -0.609, respectively.

2.2: Study of biophysical characteristics influencing the infestation rate of insect pests.

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

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 vexilluta and Vigna unguiculata*) on oviposition, mobility, food consumption and utilization by the *M.* vitrata.

Halder *et al.* (2006) observed nine plant parameters, *viz.*, pod wall thickness, number of pods/cluster, angle between the pods, trichomes of leaves, pods and stems, trichome length, pod length and pod width were studied in relation to the expression of varietal reaction towards spotted pod borer *Maruca vitrata* in ten varieties of mung bean. It was observed that highly susceptible cultivar LGG-

450 had least number of trichomes on stems (8.9), pods (3.0) and leaves (13.0) as compared to highly tolerant cultivar LGG- 497 which had 12.3, 7.2 and 22.8 trichomes/mm^2, respectively. Similarly, trichome length was also least (0.46 mm) in susceptible cultivar, LGG-450 compared to resistant cultivar, LGG- 497 (0.62mm).

Sunitha *et al.* (2008) reported that the trichomes length, density, sugars, protein and phenols were found to be associated with the resistance to *M. vitrata* in short duration pigeonpea genotypes. Trichome density on upper and lower surfaces of the leaf (390 and 452/$9mm^2$), and length (3.5 mm) and trichome density (442) and length (5.9 mm) on pods were found positively correlated with resistant genotype ICPL 98003. High sugar content in flowers (22%) and pods (10.6%) was responsible for the susceptibility of ICPL 88034, while high phenol concentration in flowers (6.5%) and pods (9.3%) in ICPL 98003 was responsible for resistance. Protein content in pods was highest (25.5%) in susceptible ICPL 88034 compared to resistant ICPL98003 (16.5%). Based on these results, ICPL 98003 was categorized as highly resistant and ICPL 98008 as moderately resistant.

Haider *et al.* (2011) Eight plant parameters, *viz.*, pod wall thickness, number of pods/cluster, angle between the pods, trichomes on leaves and stems, trichome length, pod length and pod width were studied in relation to the expression of varietal reaction towards, *Maruca vitrata* in eleven varieties of cowpea.

2.2.1: To screen out resistant/ tolerant cultivars against spotted pod borer of cowpea.

Patnaik *et al.* (1986) conducted field studies on early maturing pigeonpea varieties against pod borer and reported that ICPL 81, PUSA 33 and H76-208 had less infestation by *M. vitrata* (8.24 to10.72%) compared to 15.72 to 15.91% infestation in ICPL-I & ICPL 151 varieties.

Alghali (1993) experimented to examine the effects of four agro meteorological factors on population fluctuations in legume pod borer, *Monica testulalis* (Geyer) in two cowpea varieties was carried out under field conditions in Ibadan, Nigeria. Three peaks of the pod borer populations were observed on the cowpeas.

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 plant SDUEA-I 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 15 1 and ICPL 86012.

Sharma (1998) screened for resistance to carry out using natural infestation, and multi- and no-choice tests under greenhouse/laboratory conditions. And reported stem and pod wall thickness, trichomes and podding habit are associated with resistance to *Maruca* sp. Several natural enemies have been recorded on *Maruca vitrata* and found cultural practices such as intercropping, weeding, time of planting, and planting density to reduce its damage in cowpea. Several insecticides have been found to be effective for controlling this insect.

Akhauri *et al.* (2001) reported that susceptibility of pigeonpea genotypes against three pod boring insects viz., spotted pod borer (*Maruca testulalis* Geyer.), pod fly (*Melanagromyza abtusa* Malloch) and pod weevil (*Apion clavipes* Gerst.), on the basis of extent of pod damage in two different years, showed that the genotypes ICPL-83015 and Pusa-6 were relatively less susceptible as against ICPL-151 which was found highly prone to the borer attack under the agro-climatic conditions of North Bihar.

Mandal (2005) determined the resistance of some pigeonpea genotypes to pod borers, i.e. *Maruca testulalis* and *Helicoverpa armigera*. Pod damage varied from 7.6 to 29.3% among the test genotypes. Four short duration genotypes, i.e. ICPL 85055, ICPL 85015, ICPL 84067 and ICPL 84032, and 2 medium duration genotypes, i.e. ICPL 306 and ICPL 850046 were resistant to pod borers 5.1 to 10% pod damage. Eight short duration and 9 medium duration genotypes were moderately resistant, 5 short duration and 11 medium duration were moderately susceptible, 5 short duration and 7 medium duration were susceptible, and 2 short duration and 4 medium duration were highly susceptible.

Sunithn *et al*. (2008) screened six short duration pigeonpea genotypes for their reaction against *Maruca testulalis* (Geyer) under field, greenhouse and laboratory conditions. Field and greenhouse experiments showed significantly

lower pod damage by *Maruca* in ICPL 98003 and ICPL 98008 as compared to the susceptible genotype ICPL 88034. In greenhouse and laboratory studies showed less consumption of food and reduced larval and pupal weights of *M. testulalis* when reared on resistant genotypes like ICPL 98003 and ICPL 98008.

Chaitanya *et al.* (2012) observed from that the incidence of spotted pod borer *Maruca vitrata* (Fab) in three cultivars *viz.*, LRG 41, TRG 22 and TRG 38. Among the three cultivars, LRG-41 has recorded the highest population (17.3 larvae/ plant) followed by the TRG-22 (14.4 larvae/ plant) and the lowest pest population was recorded in the TRG-38 (9.9larvae/plant).

Randhawa and Kumar (2013) screened fifteen genotypes plus two check varieties of pigeonpea under field conditions against pod borer, *Maruca vitrata* (Geyer). On the basis of larval population, genotype AL 1743 was found promising with mean of 14.33 larvae/100 flower buds as compared with 28.00 larvae on AL 1811.

2.3: Biochemical analysis of plant parts related to resistance against major insect pests on cowpea germplasm.

Singleton *et al.* (1965) investigated and developed improved procedure and several details of the assay of total phenolic substances. The improvements include the use of Folin-Ciocalteu reagent rather than the Folin-Denis reagent, gallic acid as a reference standard, and a more reproducible time-temperature color development period. The values obtained are less subject to variation and interference from several nonphenols, yet are directly comparable to the "tannin" values obtained by the previously standard method.

Longe (1980) screened twenty varieties of cowpea with the following proximate composition: dry matter, 87–94%; crude protein, 24–33% ether extract, 1–2%; crude fibre, 2–5% and ash, 2–5% were analysed for sugar contents, starch, cell wall carbohydrates and lignin. The legume seeds exhibited a total carbohydrate content ranging from 56% to 68%, the major constituent being starch. Starch values as high as 45% to 48% were obtained for some varieties although most values ranged between 37% and 42%. Ethanol-soluble sugars were verbascose, stachyose, sucrose and raffinose in varying amounts but there were only traces of

fructose and glucose. Samples had total soluble sugar contents of 6% to 13%. Values for unavailable carbohydrates for most samples were 11% to 13%. Lignin was very low and ranged from 0·6% to 1·8%.

Macfoy *et al.* (1983) recorded a higher concentration of sugars, Amino acids and proteins in *Maruca* susceptible cowpea variety VITA 1 and lower concentrations in resistant cowpea variety TVu 946. In addition the secondary metabolites, phenols and flavonoids 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.

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*, *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.

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 my significant role in cowpea resistance to *M. vitrata.*

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.

Halder *et al.* (2006) studied on six biochemical parameters, viz., total sugar, reducing sugar, non-reducing sugar, amino acids, proteins and phenols in pods in relation to the expression of varietal reaction towards spotted pod borer *Maruca vitrata* (Geyer) in ten varieties of mungbean revealed that highly susceptible cultivar LGG-450 as compared to highly tolerant cultivar LGG- 497.

Anantharaju and Muthiah (2008) evaluated for resistance to spotted pod borer (*Maruca vitrata*) and blister beetle (*Mylabris* spp.) in 12 hybrids and 7 parental genotypes of pigeonpea under field conditions in Coimbatore, Tamil Nadu, India, during June 2003. Under unsprayed conditions, the highest grain yield and lowest yield loss were recorded for LRG 41. Among the hybrids, LRG 41 x ICPL 87119 registered the highest yield and lowest yield loss. Resistance to both pests appeared to be due to low total free amino acid content and crude protein content, and high levels of total phenol in pigeon pea genotypes.

Sujithra *et al.* (2014) evaluated for pod borers viz., *Maruca vitrata* and *Sphenarches caffer* were evaluated in 84 entries of field bean. Physical and chemical constituents of 10 selected entries were determined to establish relationship of the factors on incidence of pod damages. Studies revealed that highly susceptible cultivar AVT-FB(80)15-6-4 had highest amount of protein (28.9%), reducing sugar (1.72 mg g-1) as compared to tolerant cultivar TCR-137 which had 19.8%, 1.05, respectively. A significant positive correlation were existed between protein and reducing sugars with pod damage whereas negative correlation prevailed between silica and crude fibre contents with pod damage.

Singh *et al.* (2014) conducted experiment at the Agricultural Research Farm, Banaras Hindu University, Varanasi (UttarPradesh) twenty eight genotypes/varieties of cowpea tested against legume pod borer to find out the level of resistance. Among them eight genotypes/varieties showed resistance against legume pod borer. Rest of the genotypes/varieties showed tolerant to highly susceptible reactions to natural infestation of legume pod borer. The correlation coefficient values revealed that amount of phenol in flowers and immature pods affects adversely the infestation of legume pod borer, however, concentrations of carbohydrate and protein affects favourably.

CHAPTER - III

MATERIALS AND METHODS

The present investigation,**"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** was conducted at Horticulture research field of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G) during *Kharif,* 2015.

Geographical location

Raipur is situated in mid eastern part of Chhattisgarh in the latitude at 21°60 North and 81°36 East of 289 meters above mean sea level.

Climate

The general climate of Raipur is hot with mild winter followed by monsoon period of about four to five months. It receives an average rainfall of 1200-1400 mm per annum, concentrated mostly during June to September. The maximum temperature of this region may reach as high as 4°C during summer and minimum it may fall to 6°C during winter with high atmospheric humidity.

3.1: Status of major insect pests and natural enemies on cowpea germplasm

3.1.1: To study about the status and pest succession on cowpea

The present investigation was carried out during *Kharif season*, 2015. Sowing to maturity of the cowpea crop; how many insect pests were associated with it and in what sequence they were appeared on the crop, the insect pest succession was formulated. The details of crop field are as follows:

3.1.1.1 Experimental details

Season		*Kharif*
Crop	:	Cowpea
Germplasm	:	LOLA
Plot size	:	$20 \times 10\ m^2$

Spacing	:	40cm (row to row) × 60cm (plant to plant)
Date of transplanting	:	10/08/2015

3.1.1.2 Method of observations

Daily observations on insect pests appearance were recorded from the date of sowing to maturity of cowpea crop. After first appearance of insects, further observations were repeated at weekly interval.

Flower thrips

Monitoring for thrips should begin about 30 days after planting. Look for silver streaks on the leaves, pod and pods. Open the flower buds to look for larvae or adult thrips, or shake the flowers onto a white piece of paper and count the thrips that fall out.

Spotted pod borer

The flowers were placed in vials containing 30% alcohol and carried to the laboratory where they were dissected under the microscope and the number of *Maruca* larvae present recorded.

Pod sucking bugs

The adults and nymphs of bean bug, *Riptortus clavatus*, green stink bug, *Nezara viridula*, were observed by three observing methods such as beating, sweeping net and visual counting methods in the full bloom, full pod and beginning maturity.

To study the correlation between different insect pest population and weather parameter

The meteorological data of temperature, relative humidity, rainfall and sunshine hours during cropping period i.e. September 29/2015 to December 30/2015 is presented in table 3.3. The correlation co-efficient between different weather parameters *viz.,* maximum and minimum temperature, rainfall, relative humidity and sunshine hours and mean population counts of flower thrips, spotted pod borer and pod sucking bugs.

3.1.2.1 Statistical analysis

To study the correlation between different insect pests and their natural enemies with abiotic factors, the following formulae was used:

$$r = \frac{\sum XY - n\bar{x}\bar{y}}{\sqrt{\sum X^2 - n\bar{X}^2} \times \sqrt{\sum Y^2 - n\bar{Y}^2}}$$

where,

X = mean of 1st factor

Y = mean of 2nd factor

n = total no. of observations

r = correlation coefficient

Table 3.1. Meteorological parameter during crop season (September 29-December 2015)

Months and date	SMW	Temperature(°C)		Rainfall (mm)	Relative humidity (%)		Sunshine hours (hrs)
		Max.	Min.		Morning	Evening	
Sept24-30	39	32.5	24.6	0.0	92	57	7.2
Oct 01-07	40	33.7	24.4	0.0	92	51	7.7
Oct 08-14	41	33.9	22.2	0.0	89	47	8.7
Oct 15-21	42	33.4	22.8	0.0	91	45	8.7
Oct 22-28	43	33.7	21.3	0.0	90	37	8.2
Oct 29-04	44	30.0	19.4	0.0	90	55	6.7
Nov 05-11	45	31.7	18.8	0.0	91	37	7.8
Nov 12-18	46	31.7	16.3	0.0	89	33	7.5
Nov 19-25	47	30.6	15.5	0.0	88	36	8.3
Nov 26-02	48	31.9	16.7	0.0	87	34	7.5
Dec 03-09	49	31.2	14.8	0.0	88	31	8
Dec 10-16	50	30.1	17.3	4.4	77	46	4.4

3.2: Study of biophysical characteristics influencing the infestation rate of insect pests

The variations in morphological and biochemical traits of all germplasm were studied to their role against the cowpea spotted pod borer infestation. Therefore, the observation of different parameters *viz.*, pod colour, pod length, flower colour were tested. Pod morphological traits, pod length, pod diameter, pod weight and number of pods per plant were also taken.

3.2.1: Plant height

The plant height of five randomly selected plants from each plot was measured in cm from ground surface to top of the node of main shoot with the help of a meter rod at 70 days after sowing of cowpea plants.

3.2.2: Flower colour

Flowers colours of tested germplasm from various groups were recorded by visual observations at the time of blooming period and correlation with the percent pod damage.

3.2.3: Pod length and pod width

`The length of Pod was recorded by running a thread from joint of calyx to the apex of pod and measuring it on centimeter scale. The width of pods from each plot was recorded at the point of maximum thickness by running a thread along the girth and measuring it on a centimeter scale. It was recorded on five randomly selected pods from each plot and there average was worked out and average value was worked out.

3.2.4: Pod weight

From each germplasm, single pod was taken from five randomly selected plants and weighted in weighting machine and average value was worked out.

3.2.5: Pod shape

Pod shapes of tested germplasm from various groups were recorded by visual observations at the podding stage and correlation with the percent pod damage.

3.2.6: Pod colour

Pod colours of tested germplasm from various groups were recorded by visual observations at the podding stage and correlation with the percent pod damage.

3.2.7: Number of pods per plant

Total number of pods was counted from randomly selected five plants at 70 days after transplantation. The mean number of pods per plant was calculated by dividing the summation with five.

3.2.8: To screen out resistant/ tolerant cultivars against spotted pod borer of cowpea

Investigation was carried out to the response of thirteen germplasm of cowpea against major insect pests. (Table 3.2) Seeds of cowpea germplasm were procured from All India Coordinated Vegetable Improvement Project, Department of Horticulture, IGKV, and Raipur. The details of experiment are as follows:

3.2.8.1 Experimental details

Season		*Kharif*
Crop	:	cowpea
No. of germplasm	:	Thirteen
Design	:	Randomized Block Design (RBD)
Replications	:	Four
Plot size	:	$3.6 \times 3\ m^2$
Spacing	:	40cm (row to row) × 60cm (plant to plant)
Date of transplanting	:	10/08/2015

3.2.8.2 Method of observations

For the comparative performance of the cowpea germplasm against spotted pod borer infestation was taken on the five randomly selected plants per plot. The method of observations for this insect was same as described earlier in 3.1.1.

Table 3.2: Treatment details of experimental germplasm

Treatment	Germplasm name
T1	LOLA
T2	2015/COPBVAR.2
T3	2015/COPBVAR.3
T4	2015/COPBVAR.6
T5	2015/COPBVAR.5
T6	INDIRA LAL
T7	2014/ COPBVAR.1
T8	2014/ COPBVAR.2
T9	KASHI KANCHAN
T10	2014/ COPBVAR.4
T11	2014/ COPBVAR.5
T12	ARKA GARIMA
T13	2014/ COPBVAR.6

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 numbers of injured pods on each peduncle were then expressed as percentage. Based on the per cent pod damage, the damage score for each germplasm was calculated and were given the resistance rating 1-5 as suggested by Jackai (1982). Table 3.3

Table 3.3: Categorization of cowpea germplasm based on pod infestation.

Pod Damage (%)	Score	Resistance Rating
0-20	1	Highly resistance
21-40	2	Moderately resistance
41-60	3	Intermediate
61-80	4	Susceptible
81-100	5	Highly susceptible

3.2.8.3 Statistical analysis

The data obtained were analyzed statistically after using appropriate transformation. Transformed data was analyzed by the method of analysis of variance as described by Gomez and Gomez (1984).

The "t" test was used at 5 per cent level of significance.

Percentage of pod damage was calculated on the basis of following formula.

$$\text{Per cent pod infestation} = \frac{\text{No. of damaged pod}}{\text{Total no. of pod (Healthy +damaged)}} \times 100$$

3.3. Biochemical analysis of plant parts related to resistance against major insect pests on cowpea germplasm

Total phenol and total sugar content of cowpea germplasm were analyzed at Department of Crop Physiology, Agricultural Biochemistry and Herbal Science, IGKV, Raipur. For the estimation of phenol the method described by Sadasivam and Manikam (1996) was implied. Fresh 0.5g quantity of dried sample (leaves and pod) of identified promising germplasm was taken for the estimation of total phenol and total sugar.

3.3.1: Estimation of total phenols:

Reagents:

a) Ethanol 80% was prepared by adding 80ml of absolute alcohol in a beaker and made up to 100ml by using distilled water.
b) Sodium carbonate 20% was prepared by adding 20g sodium carbonate in 100ml of distilled water.

Preparation of working standard:

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

Procedure:

From each sample 0.5g material was weighed and was added with 10 times volume of 80% ethanol and the homogenate was centrifuged at 10,000rpm for 20 minutes. The supernatant was collected and residue was re-extracted with 5 times the volume of 80% ethanol, then centrifuged and the supernatants were pooled and evaporated to dryness. The residue was then dissolved in 5ml distilled water and different aliquots ranging from 0.2 to 2.0ml were pipette out into the test tubes and the volume in each tube was made up to 3ml by adding distilled water.

To extract 0.5ml of folin ciocalteau reagent was added and after 3minutes, 2ml of 20% sodium carbonate solution was added to each tube. The material was mixed thoroughly and tubes were placed in boiling water exactly for 1minutes. 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 concentration on X- axis and absorbance values on Y- axis.

3.3.2: Estimation of Sugar

Reagents:

a) 5% phenol- 5g of phenol was dissolved in 100ml of distilled water.
b) 96% sulphuric acid- the commercially available sulphuric acid is of 96% purity.
c) Standard glucose stock (A)- 100mg of glucose was dissolved in 100ml of distilled water in volumetric flask.

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

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

Procedure:

200mg of sample was taken in a conical flask and 5ml of 2.5N HCL was added and hydrolyzed by boiling the sample on mantle heater for 3hrs. The sample was cooled to room temperature and the volume was made up to 100ml by adding distilled water and supernatant was collected and aliquots of 0.5ml and 1.0ml were used for estimation. Aliquots of 0.5ml and 1.0ml were pipette out into different test tubes. After making up the volume to 10ml each tube with distilled water, 1.0ml of 5% phenol was added followed by 5.0ml of 96% sulphuric acid. After incubating the samples for 10 minutes at room temperature the tubes were places on a water bath set at 25-30°C for 20 minutes.

The colour developed was read at 490nm wavelength. The amount of total sugar present in samples was calculated from the standard glucose calibration curve established with different concentration (20-100mg) of glucose. The data were represented as percentage.

CHAPTER - IV

RESULTS AND DISCUSSIONS

The present investigation entitled **"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** was conducted in *kharif,* 2015 with the following objectives:-

1. Status of major insect pests and natural enemies on cowpea germplasm.
2. Study of biophysical characteristics influencing the infestation rate of insect pests.
3. Biochemical analysis of plant parts related to resistance against major insect pests on cowpea germplasm.

4.1 Status of major insect pests and natural enemies on cowpea germplasm.

The studies on the seasonal incidence revealed that insect-pests of cowpea germplasm, the occurrence of insect-pests complex began from 30 days of sowing. Observations were recorded from last week of September to third week of December, the pest incidence i.e. population of each insect was recorded on cowpea crop as per the procedure mentioned under "Materials and Methods."

The observations were recorded on major insect-pests of cowpea and their natural enemies during the experimental season i.e. *kharif*, 2015 have been presented in Table 4.1 and Fig. 4.1. The study revealed that cowpea crop was attacked by four species of insect-pests *viz*., Flower thrips **(***Megalothrips sjoestdi* Trybom*),* Pod sucking bug (*Riptorsus dentipes),* Green stink bug (*Nezara viridula)* and Spotted pod borer (*Maruca vitrata* Fab.*).*

Table 4.1: Status of major insect pest on cowpea at weekly interval, during *kharif*, 2015.

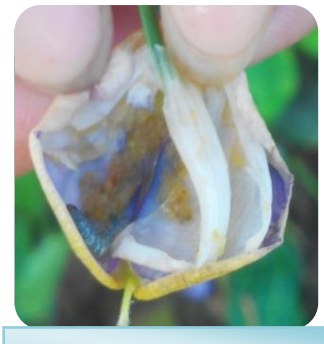
SMW	Months and date	No. of insect per plant				No. of predators per plant	
		Flower thrips (per 5 flowers/ plant)	Pod sucking bug	Green stink bug	Pod borer infestation (%)	Lady bird beetle	Spider
39	Sept24-30	3.1	0.5	0.5	10.6	0.2	0.9
40	Oct 01-07	4.3	3.5	9.3	16.7	0.3	0.4
41	Oct 08-14	2.8	4.3	5.0	13.6	0.5	1.0
42	Oct 15-21	3.0	3.3	8.3	19.7	0.6	1.4
43	Oct 22-28	2.4	3.5	5.8	14.4	0.5	1.2
44	Oct 29-04	2.3	1.5	8.0	12.1	0.2	1.6
45	Nov 05-11	2.1	9.0	12.3	12.1	0.8	0.8
46	Nov 12-18	1.7	8.8	10.5	12.1	0.8	1.0
47	Nov 19-25	2.1	7.8	9.0	9.1	1.3	1.4
48	Nov 26-02	2.4	6.8	7.3	15.2	1.5	1.4
49	Dec 03-09	1.8	4.5	12.3	12.1	1.0	1.2
50	Dec 10-16	1.5	2.5	4.3	15.2	0.8	1.0
	Mean	**2.4**	**4.6**	**7.7**	**13.6**	**0.7**	**1.1**

Among the natural enemies, two predator namely lady bird beetle *Coccinella transversalis,* spider *Neosconatheisi sp.* were observed mainly preying upon the major insect-pests *viz.,* flower thrips, pod sucking bug, green stink bug and spotted pod borer of cowpea mentioned above.

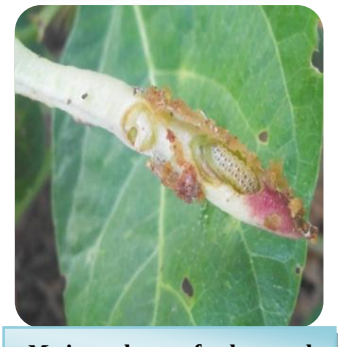
Nymph of *Nezara viridula*

Adult of *Riptorsus dentipes*

Adult of *M. sjostedti*



M.vitrata larvae feed on flower



M.vitrata larvae feed on pod

Larvae of *Maruca vitrata*

Adult of *Nezara viridula*

Eggs of *Nezara viridula*

Emerging nymph of *N. viridula*

Fig 4.1: Illustration of cowpea insect pests

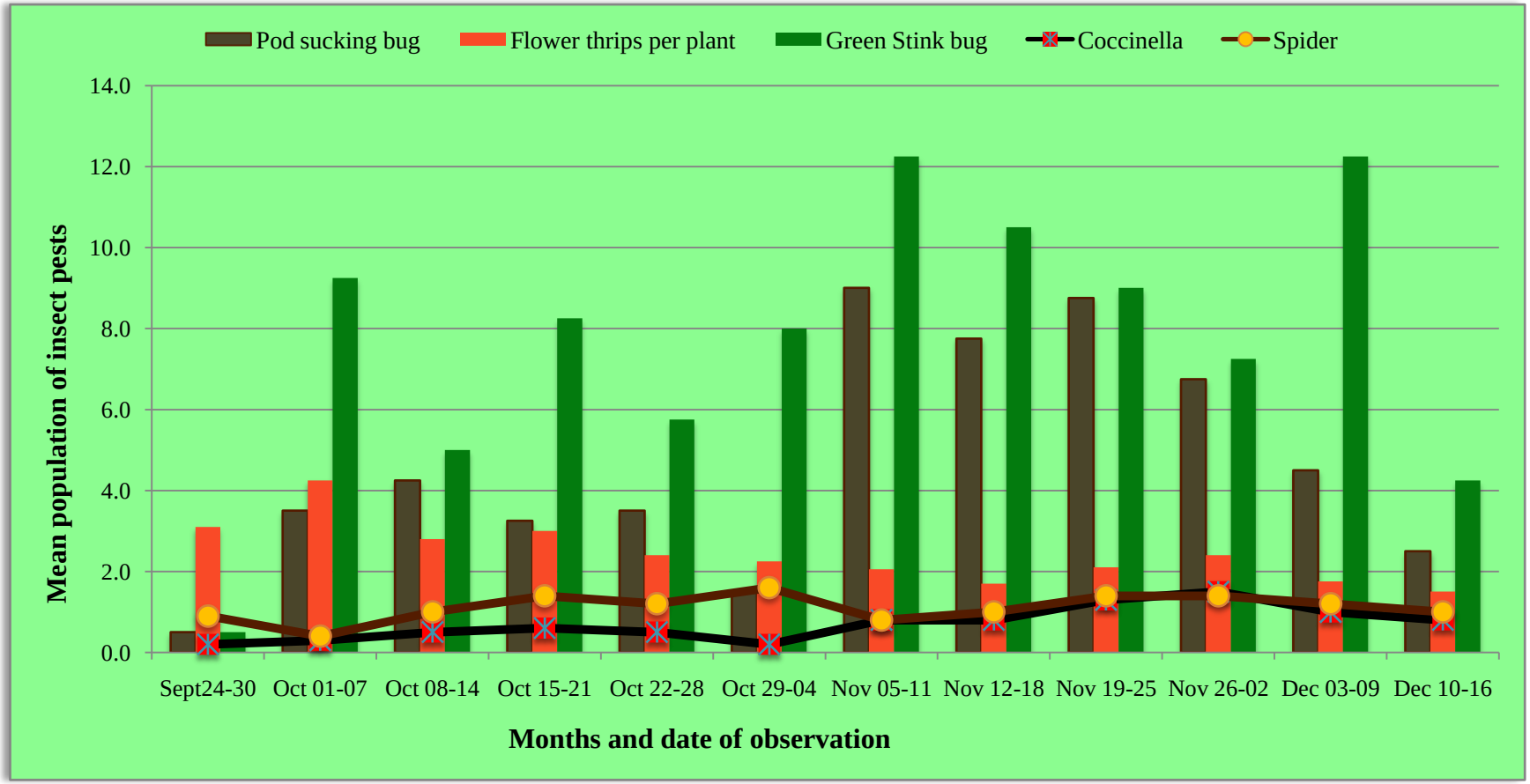


Fig. 4.2: Status of major insect-pests and natural enemies on cowpea during *kharif*, 2015.

Studies on status of insect pests on cowpea:

The other details of the insect-pests fauna together with the predatory fauna observed on cowpea, during *kharif*, 2015 along with the status of their peak activities have been presented in table 4.2 and 4.3.

4.1.1 Flower Thrips (*Megalothrips sjoestdi*)

Flower thrips affect many crops, particularly cowpea. Thrips breed in the flowers and feed on the buds and flowers. The adults are tiny, slim, elongated and shiny black are distinguished from other species of thrips by pale bands across the top of the forewings. Flower thrips infestation includes distortion, discolouration and shedding of flowers. Severe infestations that are 20 or more thrips per flower cause the flowers to fall from the plant, which prevents the pods from developing. Thrips start attacking the plant before the flowers open which causes the flowers to dry and become brown. (Africa Soil Health Consortium, 2015)

The flower thrips population ranged from 1.5 to 4.3 per plant was observed during the crop season. Flower thrips first appeared during fifth week of September (39^{th} SMW) with the population of 3.1 thrips per five flowers per plant (Table 4.1). There were continuous increases, in its population with slight fluctuation in subsequent weekly observation. The peak population of 4.3 thrips per plant was recorded during first week of October (40^{th} SMW).

The flower thrips were active throughout the crop growth. These findings are in conformity with Kumar and Kumar (2015) reported that thrips (*Megalurothrips sjostedti* Tryb.) population was observed in last week of September and its highest population was recorded in third week of October (5.87/flower bud). On the contrary, According to Patel *et al*. (2010) studied population of thrips was recorded in the month of March only and reached to its maximum level during fourth week of March. The thrips was noticed at flowering stage with varying population density. Singh and Singh (2014) recorded maximum and minimum thrips population (2.53 and 0.15 insect/flower) were observed during 25^{th} and 21^{st} SMW respectively during *zaid*, 2009-10. Yadav *et al.* (2015) revealed that thrips appeared in 35 SMW ranging from 0.2-1.2/10 flowers during flowering to pod-filling stage.

4.1.2 Pod sucking bug (*Riptorsus dentipes)*

The nymphs and adults of several different species of pod-sucking bug suck on the sap of the young pods causing them to shrivel and dry prematurely, become deformed and have reduced grain yields. Pod-sucking bug leave feeding punctures that are not easily detectable but which are responsible for the premature shrivelling of young pods and the occurrence of half-filled seeds in older pods (Singh *et al*., 1985; Jackai *et al*., 1989). These feeding punctures distinguish the pod shrivelling caused by PSB from that caused by other stresses such as drought and disease. Pod-sucking bug feed on a wide range of legumes and are very mobile, which makes them challenging to control. Monitor crops regularly to look for pod-sucking bugs and symptoms such as shrivelling and prematurely dried out pods (Pitan *et al.* 2001).

The pod sucking bug population ranged from 0.5 to 9.0 per plant was noticed during September to December months. Pod sucking bug first appeared with the mean population of 0.5 bugs per plant during fifth week of September (39^{th} SMW) (Table 4.1). There was continuous increase, in its population with slight fluctuation in subsequent observation was noticed and its peak population of 9.0 bugs per plant was recorded during second week of November (45^{th} SMW). Thereafter, there was a gradual decrease in the pest population from second week of November (46^{th} SMW) to third week of December (50th SMW) and ultimately disappeared from the crop.

In present investigation, the pod sucking was found to be active throughout the crop growth and their maximum activity was noticed during November. The pod bug activity appeared from 20^{th} standard week, increased subsequently and reached at peak level of population density during 25^{th} standard week during both the years i.e. *zaid*, 2009- 10 and 2010-11 with varying population densities (Singh and Singh 2014).

The present findings are in agreement with Yadav *et al.* (2015) revealed that pod sucking bug was observed in 35 SMW with intensity (0.8/plant) and attended its peak in 38 SMW (6/plant) which was similar to Sarma and Dutta (1996). Niba (2011) pod sucking bugs entered in cowpea fields at 8 weeks after sowing and remained on the crop till harvesting. They attained peak infestation level at 12 weeks after sowing.

Table 4.2: Insect-pests fauna on cowpea during *kharif*, 2015.

S.N.	Common name	Systemic position	Damaging stage	Range of incidence	Status of peak activity
1.	Flower thrips	*Megalurothrips sjostedti* (Thysanoptera: Thripidae)	Nymph and adult	1.5-4.3	First week of October(40th SMW)
2.	Pod sucking bug	*Riptorsus dentipes* (Hemiptera: Coreidae)	Nymph and adult	0.5-9.0	Second week of November(46th SMW)
3.	Green stink bug	*Nezara viridula* (Hemiptera: Coreidae)	Nymph and adult	0.5-12.3	Second week of November(46th SMW)
4.	Spotted pod borer	*Maruca vitrata* (Lepidoptera: Crambidae)	Larvae	9.1-19.7	Third week of October(42th SMW)

Table 4.3: Predatory fauna on cowpea during *kharif*, 2015.

S.N.	Common name	Systemic position	Insect pest preyed	Range of incidence	Status of peak activity
1.	Lady bird beetle	*Coccinella transversalis* (Coleopteran : Coccinellidae)	Thrips, lepidopterous larvae	0.2-1.5	Fourth week of November(48th SMW)
2.	Orb weaver spider	*Neosconatheisi sp.* (Araneae: Lycosidae)	Lepidopterous caterpillar, Sucking pest	0.9-1.6	Fourth week of October(43th SMW)

4.1.3 Green stink bug (*Nezara viridula)*

Nezara viridula may attacked all parts of a plant, including the stems (Panizzi and Rossi, 1991) and leaf veins, but the bugs feed mostly on podding structures and growing shoots (Todd and Herzog, 1980; Panizzi and Slansky, 1991). In general, their piercing and sucking mouthparts puncture the plant tissues and form minute, hard and brownish or blackish spots.

The population of green stink bug ranged from 0.5 to 12.3 per plant was noticed during September to December months. Green stink bug first appeared with the population of 0.5 bugs per plant during fifth week of September (39^{th} SMW) (Table 4.1). There was continuous increase, in its population with slight fluctuation in subsequent observation was noticed and its peak population of 12.3 bugs per plant was recorded during second week of November (45^{th} SMW).

In present investigation revealed that the green stink bug was found to be active throughout the crop growth and their maximum activity was noticed during November. According to Niba (2011) hemipteran pod-sucking bugs (PSBs) enter into cowpea field at 8 week after sowing and remained on the crop till harvesting. They attained peak population infestation levels at 12 WAS. *Nezara viridula and Riptortus dentipes* had low populations and was less frequent.

Pod damaged by *Riptorsus dentipes*

Pod damaged by *Riptorsus dentipes*

Fig 4.3: Illustration of damaged pod by pod sucking bug.

4.1.4 Spotted pod borer (*Maruca vitrata)*

Moths were medium-sized, with fuscous brown forewings bearing a lunulate black-edged white spot in the end of the cell. The larvae are active in evenings and fed on the plant throughout night and are photonegative (Singh and Taylor, 1978).Adults prefer to lay eggs on flower buds, flowers, terminal shoots and tender pods (Taylor, 1963).

The pod infestation was ranged from 9.1-19.7 per cent. The per cent pod infestations due to *M. vitrata* on cowpea in table 4.1. The infested pod was first appeared with 10.6 per cent infestation during last week of September (39^{th} SMW). Thereafter, there was sudden increase in pod infestation and observed its peak infestation of 19.7 per cent during third week of October (42^{th} SMW).

The present finding are in conformation with the findings of Kumar (2014) pod borer (*Maruca testulalis* Geyer) was observed first time on flower in the last week of September and recorded maximum population in first week of November (0.73/flower bud). Pod borer damage was recorded on cowpea pod first time in second week of October and maximum population was recorded in the first week of November (1.8/pod). The results indicated that the incidence *M. vitrata* commenced from the third week of November (47^{th} SMW) and remained active up to last week of January whereas the pest reached its peak level (12.6 larvae per plant) at the third week of December (51^{st} standard week), which coincides with the peak flowering stage of the crop.

Niba (2011) observed that the larvae of this insect were invading the crop at four week after sowing (47^{th} SMW). The peak level of infestation was observed at ten week after sowing (1^{st} SMW) and disappeared at thirteen week after sowing (3^{rd} SMW). Lalasangi, 1988 also reported that the peak activity of *M. vitrata has* been observed during the month of July, August and October. Similarly, Srivastava *et al*., 1992 reported two population peaks has been observed in moth catches from light traps at ICRISAT, Hyderabad i.e., first peak during September and second peak in early November to mid December, while it is between mid September to mid October at Hisar.

Patel *et al.* (2010) revealed that spotted pod borer, *M. vitrata* on cowpea was initially noticed during middle of March at pod setting stage and reached to its

highest (1.21 larvae/plant) level during fourth week of March. Yadav *et al*. (2015) revealed that population of spotted pod borer was ranging from 0.2 to 2.4 larvae per plant. The incidence of this pest started in 35 SMW and gradually increased and attended a peak 2.4 larvae/plant during 38 SMW.

Flower infested by *Maruca vitrata*

Damage symptom on pod by *Maruca vitrata*

Fig 4.4: Illustration of damaged pod and flowers by *Maruca vitrata.*

Cowpea is mainly attacked by flower thrips, pod sucking bug, green stink bug and spotted pod borer at different growth stages of the crop. To assess the potential of natural enemies of these insects on cowpea, study was undertaken during *kharif,* 2015. It revealed that following natural enemies on these insects.

Table 4.4. Correlation between natural enemies and major insect pests of cowpea during, *kharif*, 2015.

SMW	Months and date	No. of predator per plant		Incidence of insect pests			
		Lady bird beetle	Spider	Flower thrips	Pod sucking bug	Green stink bug	Pod borer damage (%)
39	Sept24-30	0.2	0.9	3.1	0.5	0.5	10.6
40	Oct 01-07	0.3	0.4	4.3	3.5	9.3	16.7
41	Oct 08-14	0.5	1.0	2.8	4.3	5.0	13.6
42	Oct 15-21	0.6	1.4	3.0	3.3	8.3	19.7
43	Oct 22-28	0.5	1.2	2.4	3.5	5.8	14.4
44	Oct 29-04	0.2	1.6	2.3	1.5	8.0	12.1
45	Nov 05-11	0.8	0.8	2.1	9.0	12.3	12.1
46	Nov 12-18	0.8	1.0	1.7	7.8	10.5	12.1
47	Nov 19-25	1.3	1.4	2.1	8.8	9.0	9.1
48	Nov 26-02	1.5	1.4	2.4	6.8	7.3	15.2
49	Dec 03-09	1.0	1.2	1.8	4.5	12.3	12.1
50	Dec 10-16	0.8	1.0	1.5	2.5	4.3	15.2
Correlation coefficient (r)=		**Lady bird beetle**		**-0.501**	**-**	**-**	**-0.136**
		Spider		**-**	**0.001**	**0.013**	**-0.095**

4.1.5: Lady bird beetle

Species of lady bird beetle, *Coccinella transversalis* was recorded as the major natural enemies of the sucking pest.

The grubs/ adults of beetle were first appeared on the crop at fifth week of September (39th SMW) with population of 0.2 beetles per plant, they were observed feeding on nymph and adults of flower thrips (Table 4.1). The activity of lady bird beetles continued up to the crop growth which coincided with peak activity of 1.5 beetles per plant during fourth week of November (48th SMW). Thereafter, decreasing trend in population was observed up to second week of

December (0.8/plant) whereas the population of lady bird beetle was ranged from 0.2 to 1.5 per plant during September to December months.

The findings of Tank and Korat (2007) reported negative correlation between *Cheilomenes sexmaculata* (Fab.) on cowpea and minimum as well as maximum temperature.

According to Singh and Singh (2014), lady bird beetles were found to be active from 21st to 26th standard week with maximum population density (0.87 insects/plant) during 25th standard week of *zaid*, 2009-10; however, during *zaid*, 2010-11, its appearance was noticed from 19th to 25th standard week with maximum population density (0.78 insects/plant) during 22nd standard week.

Similar findings were reported by Sardana and Verma (1986) the activity of *Coccinella septempunctata* Linn. was the highest after third week of March (12th standard week) at pod formation stage in summer cowpea.

According to Kumar and Kumar (2014) the experimental findings that *C. septempunctata* predators appeared in the cowpea field at 21 DAS (1.73 per plant) during the last week of August, 2007 and the maximum number of coccinellid predators (2.60 per plant) was recorded at 98 DAS during third week of November.

Patel *et al.* (2010) revealed that activity of predatory coccinellids on cowpea crop started from second week of March and continued up to harvest of crop i.e. second week of April. Major activity period of the predator was found during second fortnight of March.

4.1.6: Spiders

Predatory spiders (*Neosconatheisi sp.*) were found preying upon lepidopterous caterpillar and sucking pest. The spiders were first appeared on the crop with population of 0.9 spiders per plant during fifth week of September (Table 4.1). The peak activity of spiders was observed with population of 1.6 spiders per plant during fifth week of October (44th SMW). There was gradual decrease and reached to population of 1.0 spiders per plant during last week of December and ultimately disappeared from the crop. The population of spiders was ranged from 0.9 to 1.6 per plant during the crop season.

In the present investigation, the natural enemies, lady bird beetle and spider were observed preying upon different insect pests of cowpea. They coincided with the appearance of host insects on the crop. They were active throughout the growth period of the crop, till the last observation. From the data of table 4.4 and figure 4.1, it is evident that the population of lady bird beetle showed negative and non significant correlation with population of flower thrips (r = -0.501) and spotted pod borer (r = -0.136). Similarly, population of spiders was negatively and non significant correlation with population of spotted pod borer (r = -0.095) and positively non significant correlation was recorded on pod sucking bug (r = 0.001) and green stink bug (r = 0.013).

Lady bird beetle

Orb weaver spider

Fig 4.5: Illustration of natural enemies in cowpea crop Lady Bird beetle and Orb Weaver spider

4.1.7: To study the correlation between different insect pest population and weather parameter

The correlation coefficient among different insect pest abundance on cowpea and weather parameters were recorded and depicted on table 4.5 to 4.9 and figure 4.6 to 4.12.

The influence of different weather parameters *viz.* maximum and minimum temperature, maximum and evening relative humidity, rainfall and sunshine hours on the seasonal incidence of flower thrips, pod sucking bug and green stink bug were observed. Population of thrips and bugs were recorded on five randomly selected plants. It was statistically correlated by worked out correlation coefficient (r).

4.1.7.1: Flower thrips (*Megalothrips sjoestdi)*

Flower thrips first appeared during fourth week of September with the population of 3.1 thrips per plant (Table 4.5). It was associated with maximum temperature of 32.5°C, minimum temperature of 24.6°C, morning relative humidity of 92 per cent, evening relative humidity of 57 per cent and bright sunshine 7.2 hours. The maximum activity of cowpea flower thrips was observed during first week of October with the population of 4.3 thrips per plant, the maximum temperature of 33.7°C, minimum temperature of 24.4°C, morning relative humidity of 92 per cent, evening relative humidity of 57 per cent and bright sunshine 7.7 hours per day was prevailing.

The correlation coefficient between flower thrips population and weather parameter revealed positive and highly significant (at 1 %) with maximum temperature (r= 0.705), minimum temperature (r= 0.839) highly significant (at 1%), positive and non significant with maximum (r= 0.182), minimum (r= 0.565) relative humidity is positive and significant correlation and negatively non significant with rainfall (r= -0.390) while positive and non significant with sunshine (r= 0.369).

The present studies are corroborated with Patel *et al*. (2010) reported that none of weather variables had significant impact on occurrence of thrips. Similarly, Faleiro *et al*. (1990) also reported that relative humidity, bright sunshine hours and

vapour pressure affect negatively; while, temperature and wind speed influenced positively on the population of thrips.

Table 4.5: Average number of flower thrips (*Megalothrips sjoestdi*) on cowpea crop as influenced by different weather parameters during *kharif,* 2015.

SMW	Months and date	Flower thrips	Temperature		Relative humidity		Rainfall (mm)	Sunshine (hrs)
			Max.	Min.	Morning	Evening		
39	Sept24-30	3.1	32.5	24.6	92	57	0	7.2
40	Oct 01-07	4.3	33.7	24.4	92	51	0	7.7
41	Oct 08-14	2.8	33.9	22.2	89	47	0	8.7
42	Oct 15-21	3.0	33.4	22.8	91	45	0	8.7
43	Oct 22-28	2.4	33.7	21.3	90	37	0	8.2
44	Oct 29-04	2.3	30.0	19.4	90	55	0	6.7
45	Nov 05-11	2.1	31.7	18.8	91	37	0	7.8
46	Nov 12-18	1.7	31.7	16.3	89	33	0	7.5
47	Nov 19-25	2.1	30.6	15.5	88	36	0	8.3
48	Nov 26-02	2.4	31.9	16.7	87	34	0	7.5
49	Dec 03-09	1.8	31.2	14.8	88	31	0	8
50	Dec 10-16	1.5	30.1	17.3	77	46	4.4	4.4

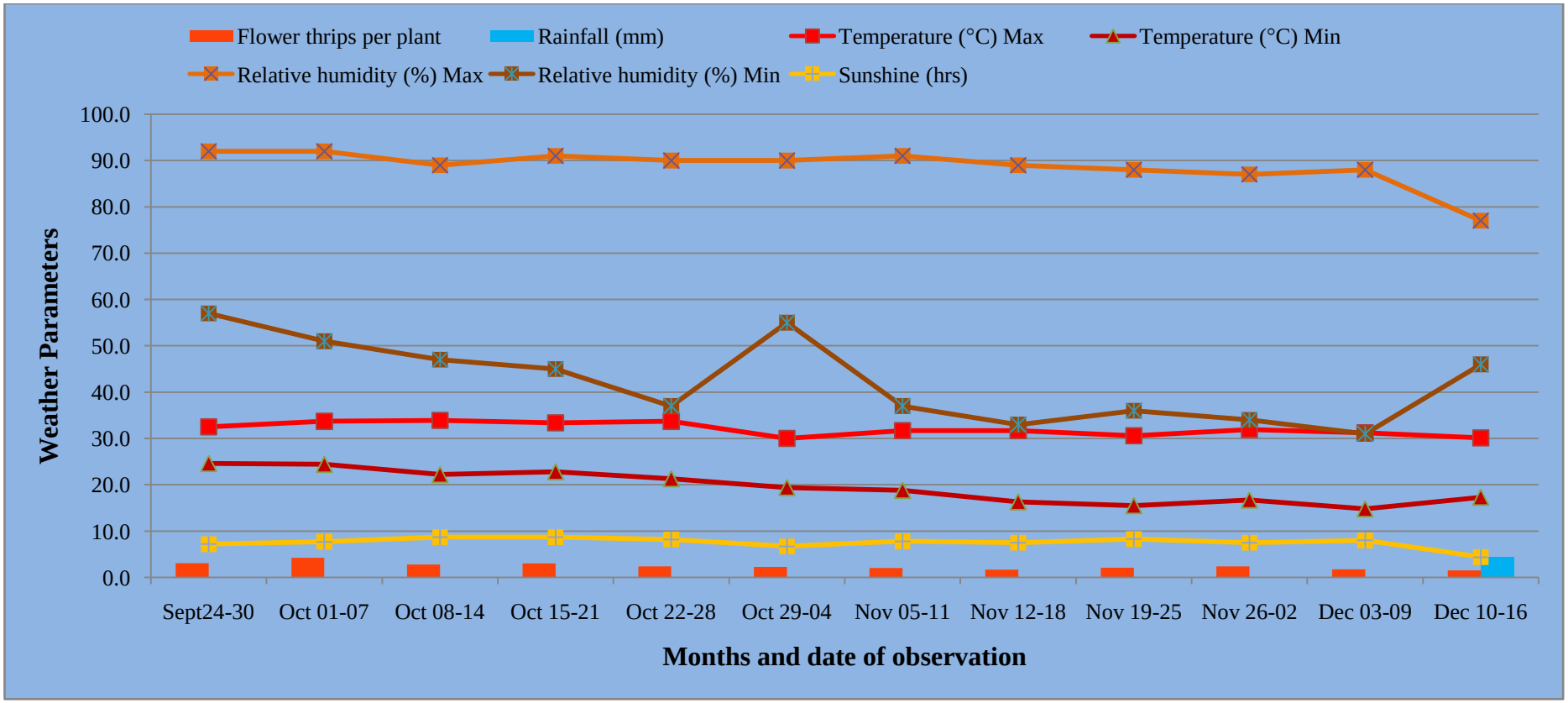


Fig. 4.6: Average number of flower thrips (*Megalothrips sjoestdi*) on cowpea crop as influenced by different weather parameters during *kharif*, 2015.

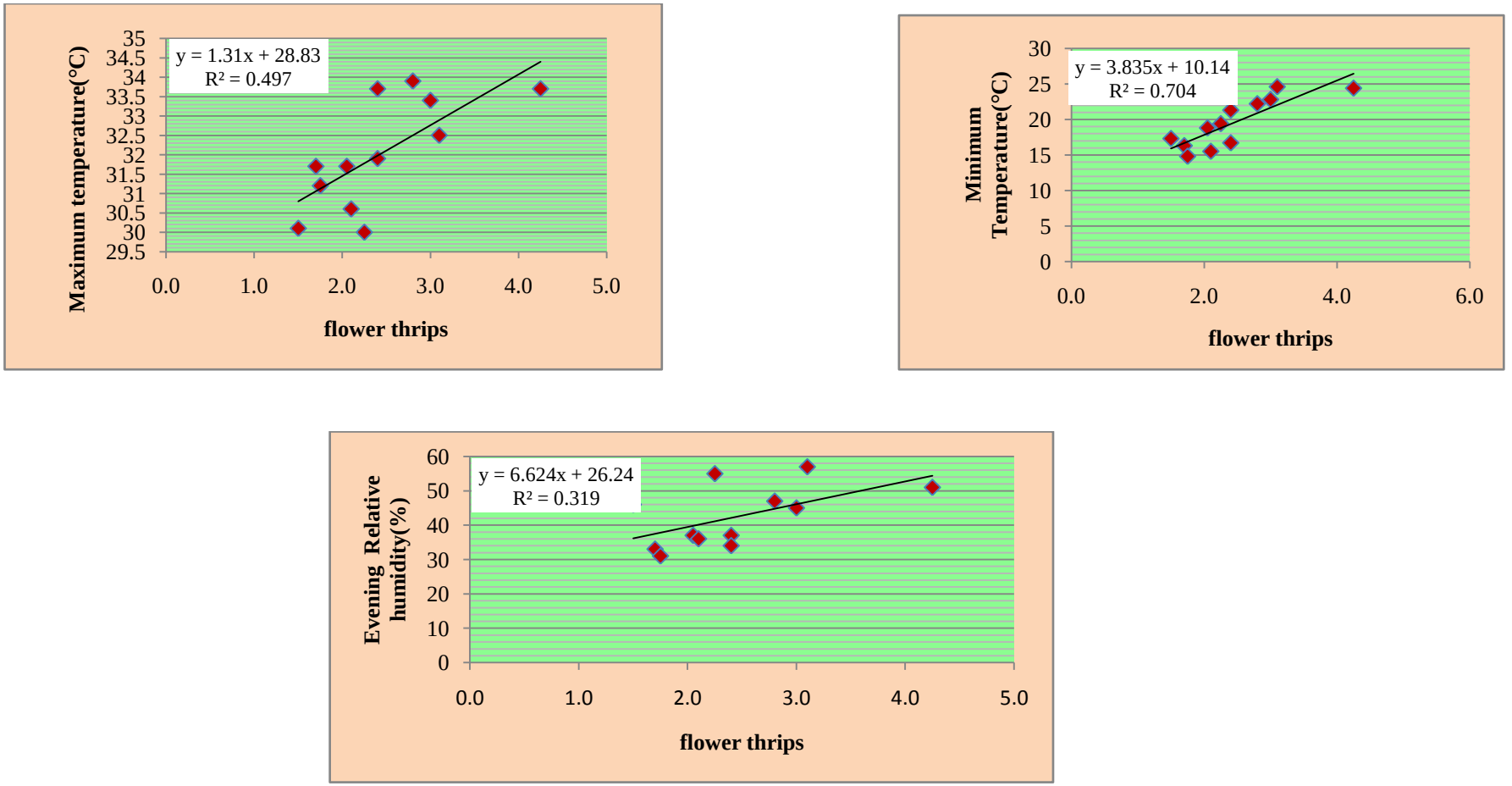


Fig. 4.7: Regression of flower thrips on Maximum Temperature (˚C), minimum temperature (˚C) and evening relative humidity (%).

4.1.7.2: Pod sucking bug

Pod sucking bug first appeared with the population of 0.9 bugs per plant during fifth week of September (Table 4.6). It was associated with the maximum temperature of 32.5°C, minimum temperature of 24.6°C, morning relative humidity of 92 per cent, evening relative humidity of 57 per cent and bright sunshine 7.2 hours per day. The population increased steadily in subsequent observations. There was a peak of 9.0 bugs per plant during first week of November. It was associated with the maximum temperature of 31.7°C, minimum temperature of 18.8°C, morning relative humidity of 91 per cent, evening relative humidity of 37 per cent and bright sunshine 7.8 hours per day.

The correlation coefficient between pod sucking bug population and weather parameter revealed negative and non significant with maximum temperature (r= -0.147), minimum temperature (r= -0.598) negatively significant (at 5%), positively and non significant with maximum (r= 0.359), minimum (r= -0.771) relative humidity is negative and highly significant (at 1%) and negatively non significant with rainfall (r= -0.241) while positive and non significant with sunshine (r= 0.330).

According to Niba (2011) revealed that none of the weather variables have significant association with occurrence of pod bug during the cropping seasons. Whereas, Bharathimeena, *et al*. (2008) reported that minimum temperature was positively correlated with the population of *Riptortus* spp.

Table 4.6: Average number of pod sucking bug (*Riptorsus dentipes*) on cowpea crop as influenced by different weather parameters during *kharif*, 2015.

SWM	Months and date	Pod sucking bug	Temperature		Relative humidity		Rainfall (mm)	Sunshine (hrs)
			Max	Min	Morning	Evening		
39	Sept24-30	0.5	32.5	24.6	92	57	0	7.2
40	Oct 01-07	3.5	33.7	24.4	92	51	0	7.7
41	Oct 08-14	4.3	33.9	22.2	89	47	0	8.7
42	Oct 15-21	3.3	33.4	22.8	91	45	0	8.7
43	Oct 22-28	3.5	33.7	21.3	90	37	0	8.2
44	Oct 29-04	1.5	30.0	19.4	90	55	0	6.7
45	Nov 05-11	9.0	31.7	18.8	91	37	0	7.8
46	Nov 12-18	7.8	31.7	16.3	89	33	0	7.5
47	Nov 19-25	8.8	30.6	15.5	88	36	0	8.3
48	Nov 26-02	6.8	31.9	16.7	87	34	0	7.5
49	Dec 03-09	4.5	31.2	14.8	88	31	0	8
50	Dec 10-16	2.5	30.1	17.3	77	46	4.4	4.4

Table 4.7: Correlation coefficient among major insect pest on cowpea and weather parameters

Mean population/ per cent infestation per plant	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Sunshine (hrs)
	Max.	Min.	Morning	Evening		
Flower thrips	0.705**	0.839**	0.182	0.565*	-0.390	0.369
Pod sucking bug	-0.147	-0.598*	0.359	-0.771**	-0.241	0.330
Green stink bug	-0.194	-0.520*	0.003	-0.620*	-0.316	0.314
Pod borer	0.490	0.405	0.152	0.127	0.178	0.023

*Significant at 5% level

**Highly significant at 1% level

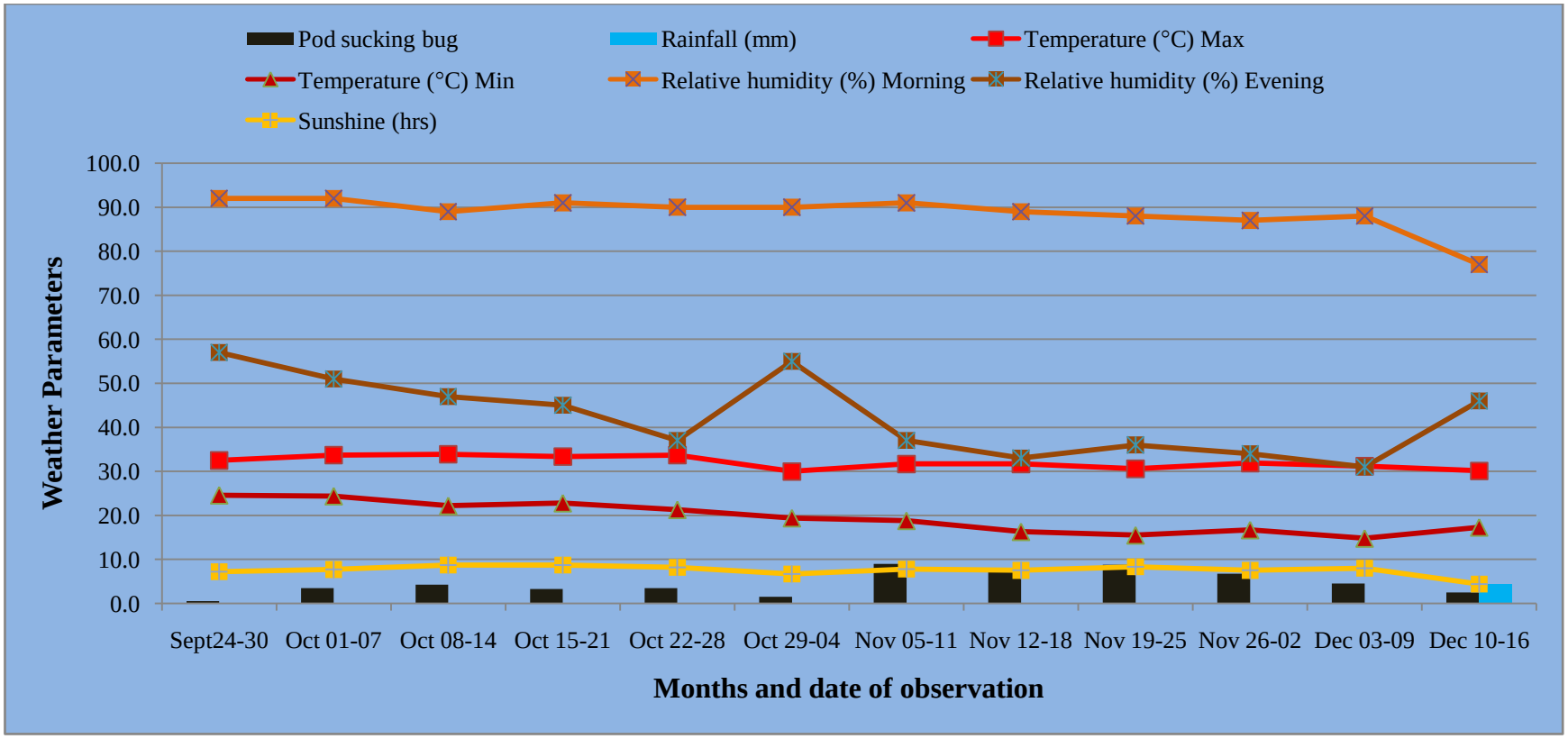
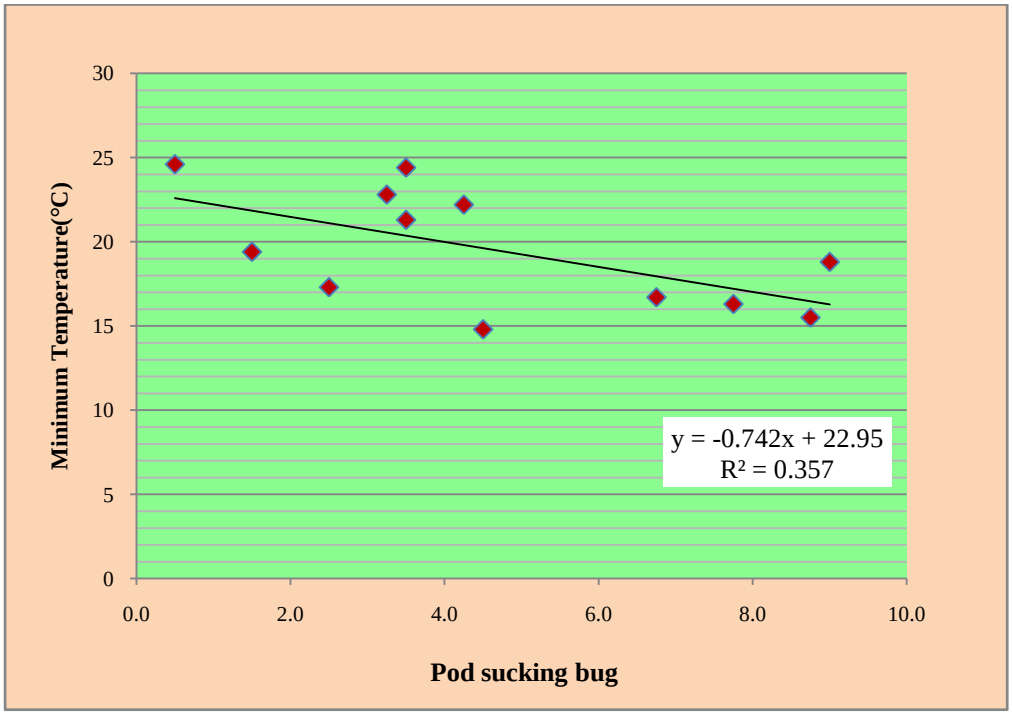


Fig. 4.8: Average number of pod sucking bug (*Riptorsus dentipes*) on cowpea crop as influenced by different weather parameters during *kharif*, 2015.



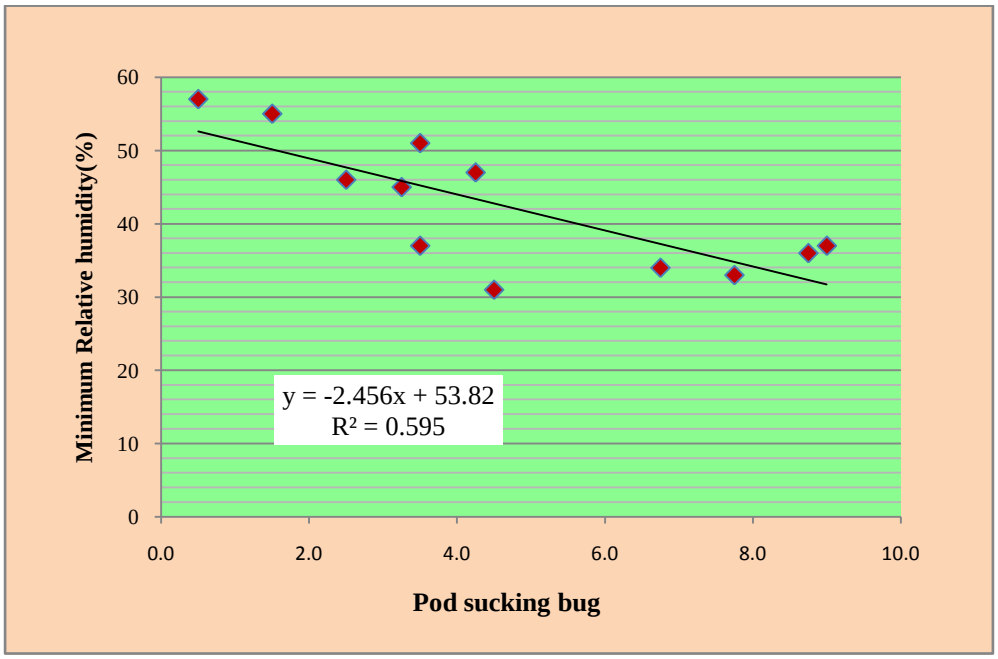


Fig. 4.9: Regression of pod sucking bug on Minimum temperature (˚C) and evening relative humidity (%).

4.1.7.3: Green stink bug

Green stink bug first appeared with the population of 0.5 bugs per plant during fifth week of September (Table 4.8). It was associated with the maximum temperature of 32.5°C, minimum temperature of 24.6°C, morning relative humidity of 92 per cent, evening relative humidity of 57 per cent and bright sunshine 7.2 hours per day. The population increased steadily in subsequent observations. There was a peak population of 12.3 bugs per plant was recorded during first week of November. It was associated with the maximum temperature of 31.7°C, minimum temperature of 18.8°C, morning relative humidity of 91 per cent, evening relative humidity of 37 per cent and bright sunshine 7.8 hours per day.

The correlation coefficient between green stink bug population and weather parameter revealed negative and non significant with maximum temperature (r= -0.194), minimum temperature (r= -0.520) negative and significant (at 5%), positively and non significant with maximum (r= 0.003), minimum (r= -0.620) relative humidity is negatively significant (at 5%) and negatively non significant with rainfall (r= -0.316) while positive and non significant with sunshine (r= 0.314).

Bharathimeena, *et al*. (2008) reported that minimum temperature was positively correlated with the population of *N. viridula* .

Table 4.8: Average number of green stink bug (*Nezara viridula*) on cowpea crop as influenced by different weather parameters during *kharif*, 2015.

SMW	Months and date	Stink bug	Temperature		Relative humidity		Rainfall (mm)	Sunshine (hrs)
			Max	Min	Morning	Evening		
39	Sept24-30	0.5	32.5	24.6	92	57	0	7.2
40	Oct 01-07	9.3	33.7	24.4	92	51	0	7.7
41	Oct 08-14	5.0	33.9	22.2	89	47	0	8.7
42	Oct 15-21	8.3	33.4	22.8	91	45	0	8.7
43	Oct 22-28	5.8	33.7	21.3	90	37	0	8.2
44	Oct 29-04	8.0	30.0	19.4	90	55	0	6.7
45	Nov 05-11	12.3	31.7	18.8	91	37	0	7.8
46	Nov 12-18	10.5	31.7	16.3	89	33	0	7.5
47	Nov 19-25	9.0	30.6	15.5	88	36	0	8.3
48	Nov 26-02	7.3	31.9	16.7	87	34	0	7.5
49	Dec 03-09	12.3	31.2	14.8	88	31	0	8
50	Dec 10-16	4.3	30.1	17.3	77	46	4.4	4.4

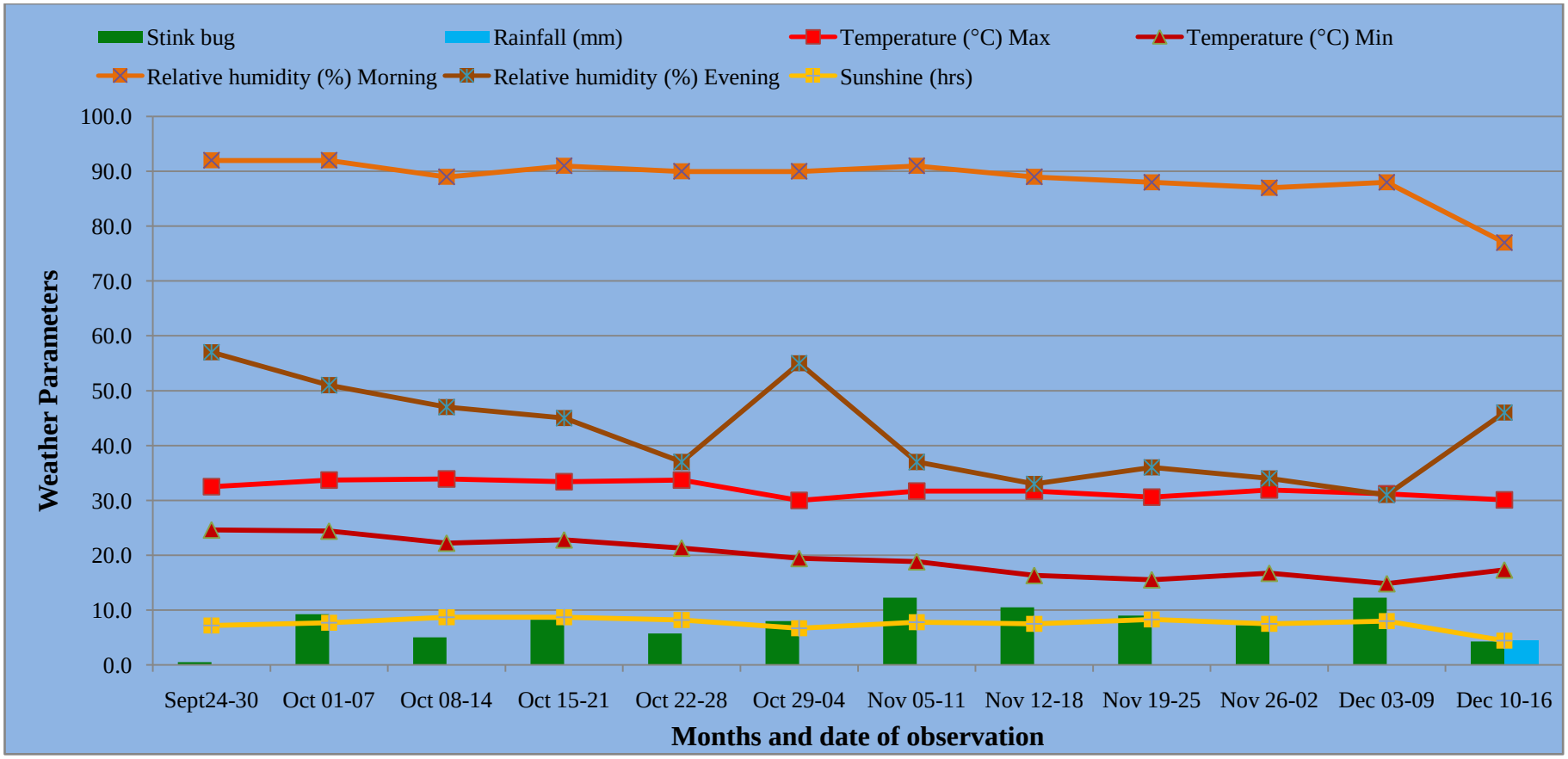
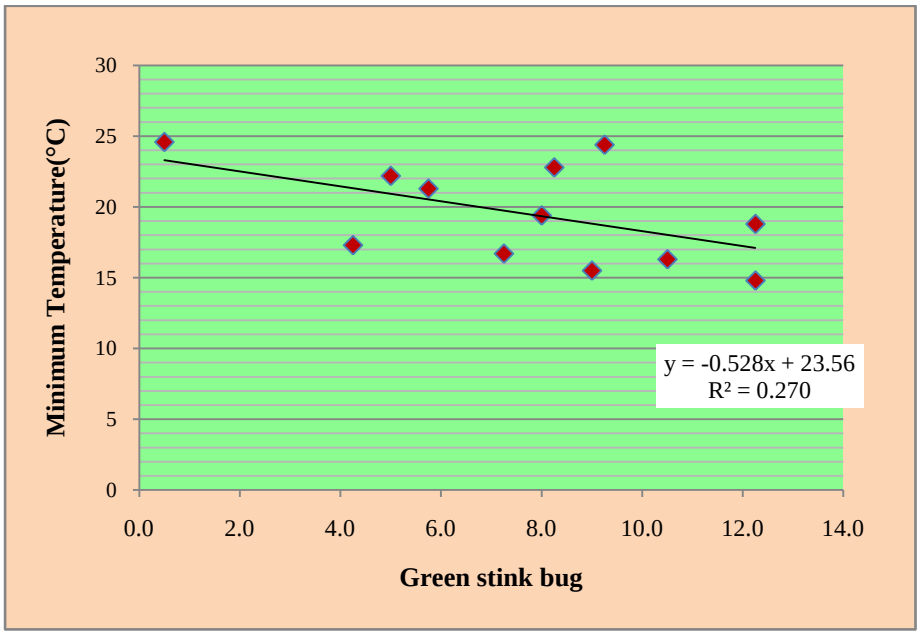


Fig4.10: Average number of green stink bug (*Nezara viridula*) on cowpea crop as influenced by different weather parameters during *kharif*, 2015.



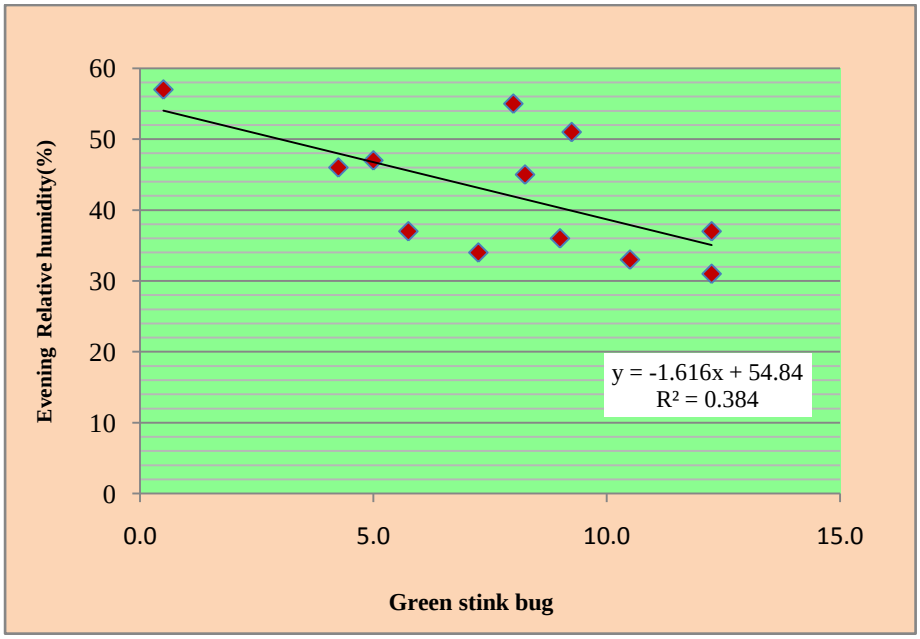


Fig. 4.11: Regression of green stink bug on minimum temperature (˚C) and evening relative humidity (%).

4.1.7.4: Spotted pod borer (*Maruca vitrata)*

The per cent pod infestations due to *M. vitrata* on cowpea germplasm were presented in table 4.9. The infested pod was first appeared with 10.6 per cent infestation during third week of September (39th SMW). It was associated with the maximum temperature of 32.5ºC, minimum temperature of 24.6ºC, morning relative humidity of 92 per cent, evening relative humidity of 57 per cent and bright sunshine of 7.2 hours per day was prevailing. There was steady increase with slight fluctuations in pest activity was observed in subsequent observations and peak pod infestation per cent was recorded during third week of October. It was associated with the maximum temperature of 33.4ºC, minimum temperature of 22.8ºC, morning relative humidity of 91 per cent, evening relative humidity of 45 per cent and bright sunshine 8.7 hours per day.

The correlation coefficient between spotted pod borer population and weather parameter revealed positive and non significant with maximum temperature (r= -0.490), minimum temperature (r= 0.405), maximum (r= 0.152), minimum (r= -0.127) relative humidity, rainfall (r= 0.178) and sunshine (r= 0.023).

Ganapathy (1996) revealed that relative humidity and rain fall had positive correlation while temperatures had negative influence on pest incidence. Reddy *et al.*, 2001; Sahoo and Behera, 2001; Akhilesh and Paras, 2005 recorded that high temperatures, high relative humidity and rainfall favour the population build up which leads to severe infestation in cowpea.

Yadav *et al.* (2015) revealed that correlation of spotted pod with weather factors exhibited significantly negative correlation with minimum and average temperature and highly significant with age of crop.

Patel *et al.* (2010) revealed that there was significant negative association between the larval population of *M. vitrata* and morning relative humidity (r = -0.809) as well as average relative humidity (r = -0.771). Temperature, bright sunshine hours, wind speed and vapour pressure exhibited positive influence on *M. vitrata*, but none of them was significant. Relative humidity showed significant negative correlation, whereas average temperature (r= 0.679) and bright sunshine hours (r= 0.686) showed significant positive correlation with coccinellid population on cowpea crop.

According to Kumar and Kumar (2014) observed high degree of significant negative correlation was noticed between mean maximum temperature and the larval population of pod borer in flower bud (r= -0.8788), and pod (r= -0.8602) indicating a decline in larval population with an increase in mean maximum temperature. On contrary, the morning relative humidity had a highly significant positive correlation with population of pod borer larvae in flower bud (r=0.8778) and pod (r=0.9450), indicating the increase in larvae population with an increase in morning relative humidity. A highly significant negative correlation (r= - 0.9080) existed between wind velocity and population of pod borer larvae per pod, indicating the decline in larval population with an increase in wind velocity. Similar findings have also been reported by Ke *et al.* (1985), Veeranna *et al.* (1997) and Bachatly and Malak (2001). Oghiakhe *et al.* (1991) obtained a positive correlation of percentage pod damage and larval infestation of *M. testulalis* in flowers with relative humidity, and negative correlation with temperature.

The larval population showed significant negative correlation with minimum temperature (Thejaswi *et al*., 2008; Shivaraju *et al*., 2008; Chittibabu *et al*.,2009; Umbarkar *et a*l., 2010; Sonune *et al*., 2010), significant positive correlation with rainfall (Gopali *et al*., 2008) and morning relative humidity (Chittibabu *et al*., 2009) in blackgram.

Table 4.9: Average number of spotted pod borer (*Maruca vitrata*) on cowpea as influenced by different weather parameters during *kharif*, 2015.

SMW	Months and date	Pod borer infestation (%)	Temperature		Relative humidity		Rainfall (mm)	Sunshine (hrs)
			Max.	Min.	Morning	Evening		
39	Sept24-30	10.6	32.5	24.6	92	57	0	7.2
40	Oct 01-07	16.7	33.7	24.4	92	51	0	7.7
41	Oct 08-14	13.6	33.9	22.2	89	47	0	8.7
42	Oct 15-21	19.7	33.4	22.8	91	45	0	8.7
43	Oct 22-28	14.4	33.7	21.3	90	37	0	8.2
44	Oct 29-04	12.1	30.0	19.4	90	55	0	6.7
45	Nov 05-11	12.1	31.7	18.8	91	37	0	7.8
46	Nov 12-18	12.1	31.7	16.3	89	33	0	7.5
47	Nov 19-25	9.1	30.6	15.5	88	36	0	8.3
48	Nov 26-02	15.2	31.9	16.7	87	34	0	7.5
49	Dec 03-09	12.1	31.2	14.8	88	31	0	8
50	Dec 10-16	15.2	30.1	17.3	77	46	4.4	4.4

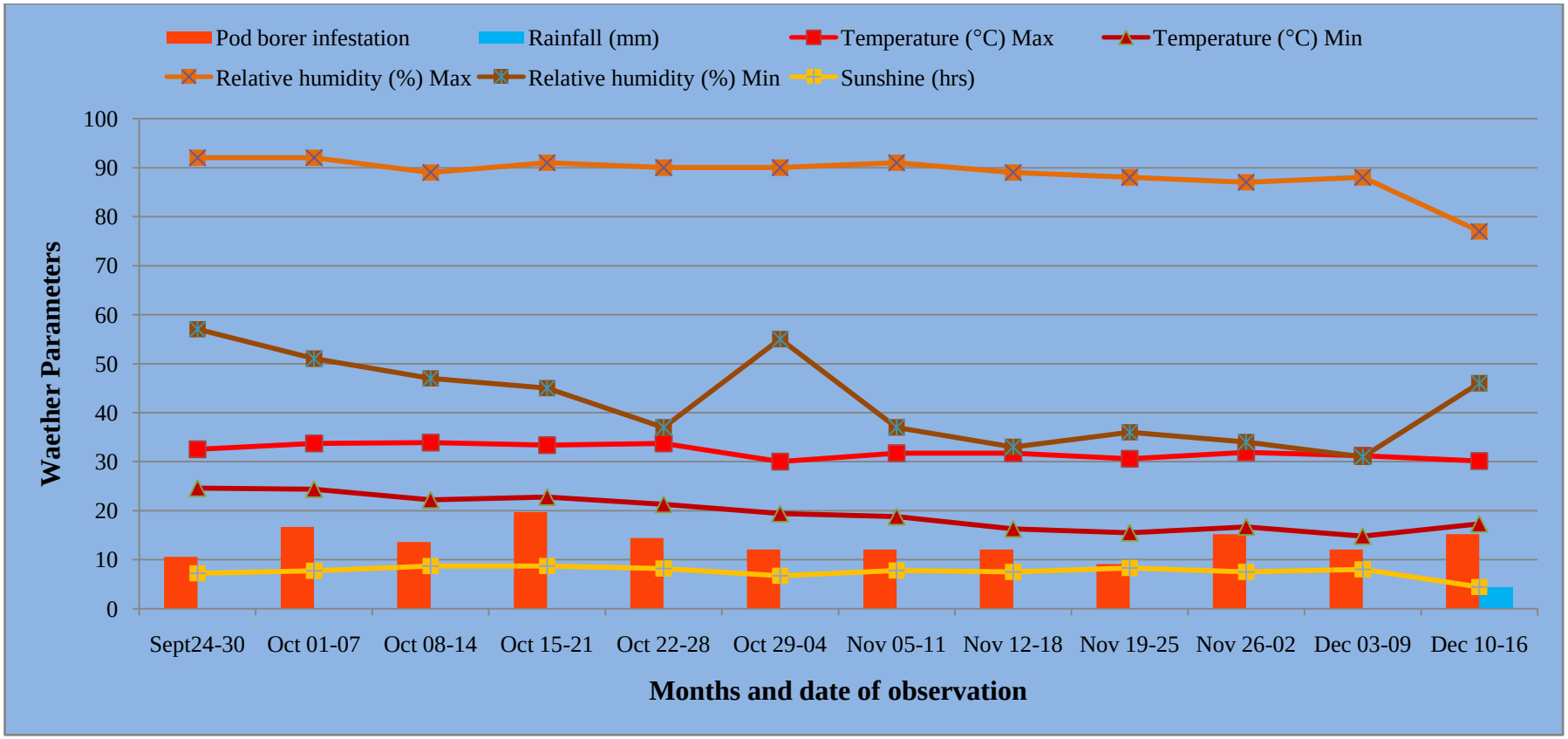


Fig 4.12: Pod borer infestation (*Maruca vitrata*) on cowpea as influenced by different weather parameters during *kharif*, 2015.

4.2: To identify the biophysical traits influencing the infestation rate of cowpea spotted pod borer.

4.2.1 Plant height of cowpea germplasm

Plant heights of thirteen cowpea germplasm were determined at 70 days after sowing (table 4.11). The plant height was ranged from 93.25cm i.e., 2014/ COBVAR-6 to 257.75cm i.e., 2015/ COBVAR-2 with mean pod infestation range of 13.94 to 11.84 per cent.

From the data recorded, per cent pod borer infestation showed positive and non significant correlations with plant height at 70 DAS (r = 0.126). The relation of pest infestation with plant height tended to be linear as indicated by regression line equation (y = 0.016x + 14.56) at 70 DAS (Figure 4.11).

4.2.2: Flower colour

Flower colour of cowpea germplasm was observed by visual observation. They were grouped into five flower colour i.e., creamy white, purplish white, white, purple and light purple (Table 4.10). Out of thirteen germplasm five germplasm had purple colour i.e., 2015/ COBVAR-3, Lola, 2014/ COBVAR-6 and Kashi Kanchan; one germplasm had purplish white i.e., 2014/ COBVAR-1; two had light purple i.e., 2015/ COBVAR-5, 2014/ COBVAR-2; two had creamy white 2015/ COBVAR-2, 2014/ COBVAR-4 and other three had white colour *viz.*, Indira Lal, 2015/ COBVAR-6 and 2014/ COBVAR-5 respectively.

Saxena *et al.* (2002) screened total of 271 pigeonpea accessions for resistance to *M. vitrata* in an experiment conducted in Patancheru, Andhra Pradesh, India. The reaction of lines selected from the promising accessions was also evaluated. Screening of the genotype accessions revealed large variation in *M. vitrata* damage to flowers and pods. On average, the *M. vitrata* damage in determinate accessions (66-75%) was higher than that of non determinate accessions (41-50%). Resistant plants from four determinate and 12 non determinate accessions were selected.

Pod related parameters viz., pod length (cm), pod width (cm), pod weight (g), pod shape, pod colour and number of pods per plant and their relation with overall mean shoot and pod borer infestation was undertaken. The results obtained have been depicted on table 4.11 and as here below.

Table.4.10: Correlation between morphological characters of pod, leaves and flower colour with pod infestation on Cowpea germplasm

Germplasm	Pod colour (Green/ Light green/ dark green)	Pod shape (Straight/ slightly curved/ round flat/ flat)	Leaf Colour (light green / dark green)	Flower Colour (purple/ White/ creamy white/ light purple)	Pod borer infestation (%)
2015/ COPBVAR-2	Light green	Slightly curved	Light green	Creamy white	11.84
2015/ COPBVAR-3	Red	Slightly curved	Dark green	Purple	23.91
INDIRA LAL	Red	Slightly curved	Dark green	White	22.66
2015/ COPBVAR-5	Green	Slightly curved	Dark green	Light purple	41.91
2015/ COPBVAR-6	Green	Slightly curved	Light green	White	14.86
LOLA	Green	Slightly curved	Light green	Purple	13.66
2014/ COBVAR-1	Light green	Curved	Dark green	Purplish white	13.59
2014/ COBVAR-2	Light green	Straight	Dark green	Light purple	16.39
2014/ COBVAR-4	Green	Straight	Light green	Creamy white	17.83
2014/ COBVAR-5	Light green	Straight	Dark green	White	15.34
2014/ COBVAR-6	Light green	Straight	Dark green	purple	13.94
Kashi Kanchan	Green	Straight	Dark green	Purple	7.45
Arka Garima	Green	Straight	Light green	Purple	12.74


ARKA GARIMA


KASHI KANCHAN


2014/COPBVAR 6


INDIRA LAL


LOLA


2015/COPBVAR 2


2015/COPBVAR 6


2015/COPBVAR 3


2014/COPBVAR 1


2014/COPBVAR 2


2014/COPBVAR 5


2014/COPBVAR 4


2015/COPBVAR 5

Fig 4.13: Illustration of flower colour in different cowpea germplasm

Table 4.11: Correlation between pod morphological characters and pod infestation on Cowpea germplasm

Germplasm	Pod length (cm) (Avg. of 10 pods)	Pod circumference/ girth (cm) (Avg. of 10 pods)	Number of pods / plant (Avg. of 5 plants)	Pod weight (g) (Avg. of 20 pods)	Pod borer infestation (%)	Plant height (cm) Av of 10 plants
2015/ COPBVAR-2	28.13	2.70	22.38	9.80	11.84	257.75
2015/ COPBVAR-3	45.30	1.93	16.06	11.68	23.91	248.5
INDIRA LAL	60.50	3.05	11.26	22.00	22.66	226
2015/ COPBVAR-5	94.25	2.93	9.09	23.65	41.91	167.75
2015/ COPBVAR-6	51.53	2.85	21.34	18.85	14.86	237.5
Lola	54.00	2.95	16.52	19.75	13.66	224.25
2014/ COBVAR-1	26.08	3.00	23.42	7.51	13.59	101.9
2014/ COBVAR-2	35.26	3.00	16.45	7.62	16.39	101.05
2014/ COBVAR-4	26.62	2.55	16.32	6.25	17.83	102.3
2014/ COBVAR-5	39.39	3.08	13.30	8.20	15.34	111.2
2014/ COBVAR-6	25.05	2.50	23.75	8.15	13.94	93.25
Kashi Kanchan	27.45	2.98	22.69	6.89	7.45	165.35
Arka Garima	20.35	3.11	29.59	7.69	12.74	126.4
Range	20.35-94.25	1.93-3.11	9.09-29.59	6.25-23.65	7.45-41.91	93.25-257.75
Mean	41.07	2.82	18.63	12.16	17.35	166.40
Correlation Coefficient	0.849**	-0.153	-0.715**	0.628*	-	0.126

***Significant at 5% level**

****Highly significant at 1% level**

4.2.3: Pod length and pod width of cowpea

The mean pod length of cowpea germplasm ranged from 20.35 cm to 94.25cm with a mean of 41.07 (Table 4.11). Among the thirteen germplasm, the maximum pod length 94.3 cm was recorded on 2015/ COPBVAR-5 which had 2.9 cm pod width and 41.91 per cent pod borer infestation. The second maximum pod length of 60.5 cm was recorded on Indira lal which had 3.1 cm pod width and 22.66 per cent pest infestation. The smallest pod of 20.4 cm was observed on Arka Garima with 3.1 cm pod width and pest infestation of 12.74 per cent followed by 25.1 cm on 2014/COPBVAR-6 with 2.5 cm pod width which had 13.94 per cent infestation.

Halder *et al*. (2006) revealed that the correlation between pod length and incidence was positive and significant. Lengthy pods were found more susceptible to *M. vitrata*. These observations are in agreement with the findings of Sharma (2004). The results pertaining to pod width revealed that pods of LGG- 497 were significantly broader as compared to others. Negative and significant correlation existed between pod width and incidence of *M. vitrata.*

In case of pod width, it ranged from 1.93 cm to 3.11cm with a mean of 2.82cm. The maximum pod width 3.11cm with 20.35cm pod length was recorded on Arka Garima followed by 3.08 cm width with 39.39cm length on 2014/COPBVAR-5 which had pod borer infestation of 12.74 and 15.34 per cent, respectively. The minimum pod width 1.93cm with 45.3cm length was recorded on 2015/COPBVAR-3 followed by 2.5cm width with 25.05cm length on 2014/COPBVAR-6 which had pest infestation of 23.91 and 13.94 per cent, respectively.

Correlation studies of per cent cowpea pod borer infestation with pod length ($r = 0.849$) showed positive and highly significant relation (at 1%) and pod width ($r = -0.153$) showed negative and non significant relation.

Halder *et al*. (2006) confirmed that negative and significant correlation between pod width and pod damage as indicated in TCR -137 were in conformity with the observations of Chaudhary and Kumar (2000) in pigeon pea.

Sujithra *et al.* (2012) revealed through correlation studies that pod length was positively related with pod damage, while, negative and significant correlation was established between pod width of field bean and pod damage by spotted pod borer.

4.2.4: Pod weight

Among thirteen germplasm, the pod weight ranged from 6.25g to 23.65g with a mean of 12.16g. The maximum pod weight of 23.65g on 2015/COPBVAR-5 which had 41.91 per cent pod borer infestation followed by 22.00g on Indira Lal with 22.66 per cent infestation while lowest pod weight of 6.25g was recorded on 2014/ COBVAR-4 which had 17.83 per cent infestation followed by 6.89g on Kashi Kanchan with 7.45 per cent infestation.

The correlation studies of per cent cowpea pod borer infestation with pod weight showed positive and significant relation with pod weight (r = 0.628) (at 5%).

4.2.5: Pod shape

Pod shape of cowpea germplasm was observed by visual observation. They were grouped into four pod shape i.e., slightly curved; straight and curved (Table 4.10). Out of thirteen germplasm six germplasm had straight i.e., 2014/ COPBVAR-2, 2014/ COPBVAR-4, 2014/ COPBVAR-2, 2014/ COPBVAR-5, 2014/ COPBVAR-6, Kashi kanchan and Arka garima and six had slightly curved in shape i.e., 2015/ COPBVAR-2, 2015/ COPBVAR-3, Indira Lal, 2015/ COPBVAR-5 and 2015/ COPBVAR-6 and one had curved pod shape *viz.*, 2014COPBVAR-1. This cowpea germplasm were highly resistant to spotted pod borer.

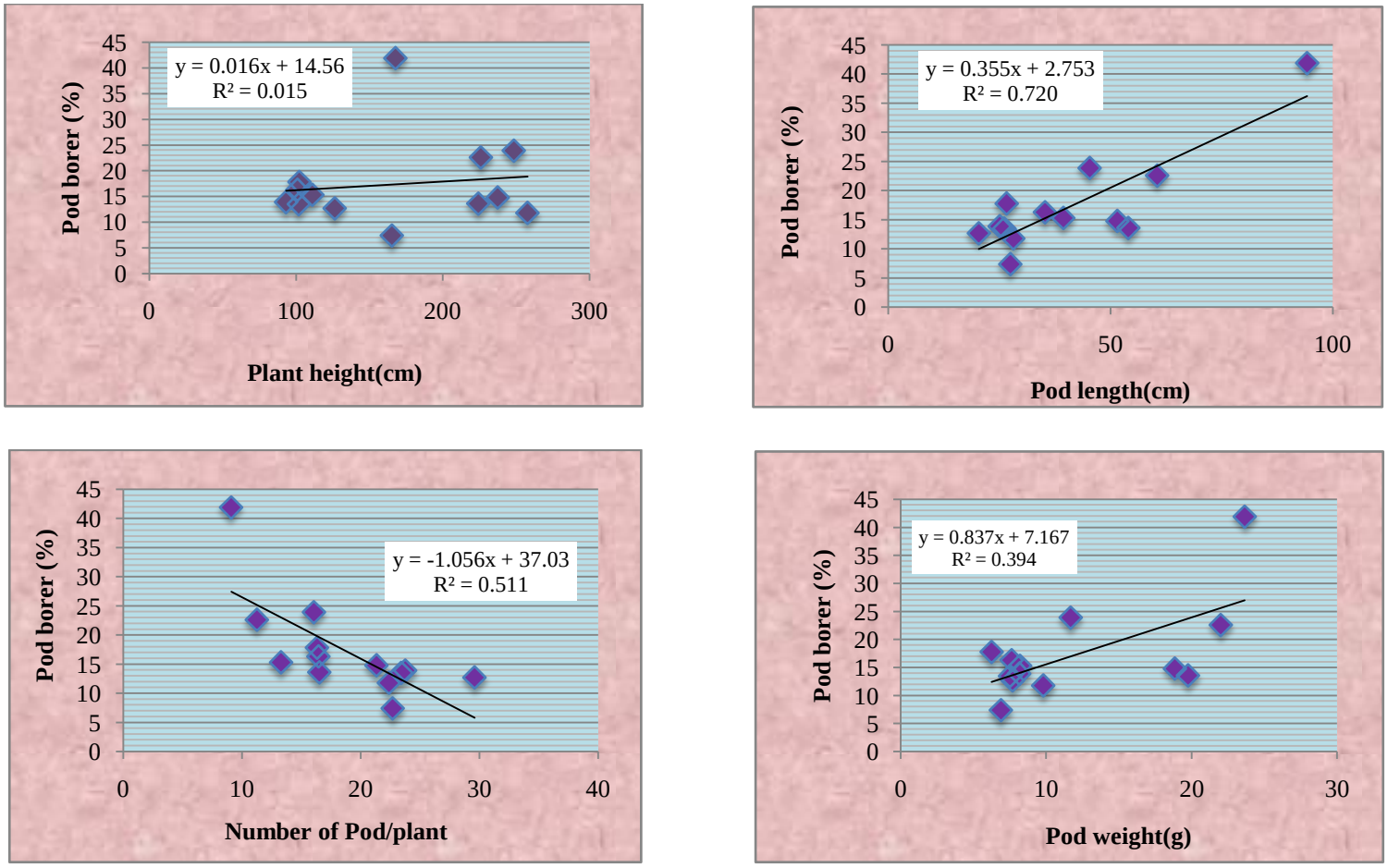


Fig 4.14: Regression of plant and pod morphological characters with pod borer damage

2014/COPBVAR 1

2014/COPBVAR 2

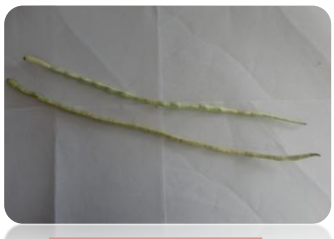
KASHI KANCHAN

2014/COPBVAR 5

2014/COPBVAR 6

ARKA GARIMA

2014/COPBVAR 4



LOLA

2015/COPBVAR 2

2015/COPBVAR 3

2015/COPBVAR 5

2015/COPBVAR 6

INDIRA LAL

Fig 4.15: Illustration of pod images of cowpea germplasm

4.2.6: Pod colour

Pod colour of cowpea germplasm was observed by visual observation. They were grouped into three pod colour i.e., red, light green and green (Table 4.10). Out of thirteen germplasm seven germplasm had green colour i.e., 2015/ COPBVAR-5, 2015/ COPBVAR-6, Lola, 2014/ COPBVAR-4, Kashi Kanchan and Arka Garima; four germplasm had light green i.e., 2015/ COPBVAR-2, 2014/ COPBVAR-1, 2014/ COPBVAR-2, 2014/ COPBVAR-5 and 2014/ COPBVAR-6 and other two had red colour *viz.*, Indira lal and 2015/ COPBVAR-3 pods were showed red colour. These cowpea germplasm were moderately resistant to spotted pod borer.

4.2.7: Number of pods per plant

Among thirteen germplasm, the range of number of pods was 9.09 to 29.59 per plant with a mean of 18.63 (Table 4.11). The least number of 9.09 pods per plant was found on 2015/ COPBVAR-5 which had 41.91 per cent pod borer infestation followed by 11.26 on Indira Lal with 22.66 per cent infestation while maximum 29.59 pods per plant was found on Arka Garima which had 12.74 per cent infestation, respectively.

The correlation studies of per cent cowpea pod borer infestation with number of pods per plant showed negative and highly significant relation (at 1%) (r = – 0.715).

4.2.8: To screen out resistant/ tolerant cultivars against spotted pod borer (*Maruca vitrata)* of cowpea

The overall mean percentages of pod borer infestation due to *M. vitrata* on thirteen germplasm were recorded during *kharif* 2015. The ranged from 7.45 to 41.91 per cent (Table 4.12) in different germplasm, accordingly the germplasm were categorized as per their reaction pattern.

The result presented on table no. 4.12, among the germplasm, ten germplasm were recorded as a highly resistance, with overall mean pod borer infestation between 0.00 and 20.00 per cent and two germplasm were observed as a moderately resistance comprised with overall mean pod borer infestation between 21.00 and 40.00 per cent infestation while germplasm 2015/COPBVAR-5 was showed intermediate reaction i.e., infestation ranged from 41.00 and 60.00 per cent. None of the germplasm was recorded as a susceptible against cowpea spotted pod borer with overall mean pod borer infestation between 61.00 and 80.00 per cent.

Table 4.12: Screening against major insect pests and yield (q/ha) of cowpea

Germplasm	Pod Borer Infestation (%)	Flower thrips	Pod sucking bug	Green stink bug	Green pod yield q/ha
2015/COPBVAR-2	11.84 (9.08)**	10.9 (3.4)*	4.7 (2.3)	6.3 (2.6)	87.91
2015/COPBVAR-3	23.91 (11.07)	13.1 (3.7)	4.1 (2.2)	6.8 (2.7)	66.77
INDIRA LAL	22.56 (8.91)	7.6 (2.8)	5.8 (2.5)	6.1 (2.5)	71.31
2015/COPBVAR-5	41.91 (10.85)	8.7 (3.0)	5.5 (2.5)	6.1 (2.5)	52.25
2015/COPBVAR-6	14.76 (9.99)	14.6 (3.9)	4.2 (2.2)	6.8 (2.7)	162.37
LOLA	13.56 (8.40)	12.1 (3.6)	4.6 (2.3)	7.7 (2.9)	115.16
2014/COPBVAR-1	13.49 (10.00)	9.4 (3.0)	5.2 (2.4)	8.5 (3.0)	125.49
2014/COPBVAR-2	16.29 (9.14)	6.3 (2.5)	5.1 (2.4)	8.7 (3.0)	87.21
2014/COPBVAR-4	17.83 (9.59)	5.9 (2.5)	6.1 (2.6)	6.7 (2.7)	73.31
2014/COPBVAR-5	15.34 (7.99)	4.9 (2.3)	7.4 (2.8)	7.0 (2.8)	78.36
2014/COPBVAR-6	13.94 (10.31)	10.5 (3.0)	8.6 (2.9)	8 (2.9)	139.39
KASHI KANCHAN	7.45 (7.02)	7.3 (2.7)	5.9 (2.5)	7.3 (2.8)	111.94
ARKA GARIMA	12.74 (10.97)	4.9 (2.3)	6.9 (2.7)	7.6 (2.9)	161.06
Range	7.45-41.91	4.9- 14.6	4.1-8.6	6.1-8.7	52.25-162.37
overall mean	2.91 (9.49)	8.9 (3.0)	5.7 (2.5)	7.2 (2.8)	
Sem ±	0.508	0.202	0.106	0.128	
CD	1.424	0.564	0.296	0.359	

***Figures in parenthesis are square root transformed value.**

****Figures in parenthesis are arcsine transformed value.**

Table 4.13: Screening of cowpea germplasm resistance against spotted pod borer (*Maruca vitrata)*

Level of infestation (%)	Germplasm	Category	Grade	Score
0-20	2015/ COPBVAR-2, 2015/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR- 2, 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, KASHI KANCHAN,LOLA,ARKA GARIMA	Highly Resistance	HR	1
21-40	2015/ COPBVAR-3, INDIRA LAL	Moderately Resistance	MR	2
41-60	2015/ COPBVAR-5	Intermediate	I	3
61-80	None	Susceptible	S	4
81-100	None	Highly Susceptible	HS	5

During investigation it was noticed that among the germplasm, ten germplasm i.e., 2015/COPBVAR-2, 2015/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-2, 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, KASHI KANCHAN, LOLA, ARKA GARIMA were showed highly resistance against spotted pod borer of cowpea whereas, three germplasm i.e., 2015/COPBVAR-3, 2015/COPBVAR-4 and INDIRA LAL were recorded moderately resistance and only one germplasm i.e., 2015/ COPBVAR-5 was found intermediate reaction respectively.

During *kharif* 2015 the mean population of green stink bug showed singnificant differences among the tested germplasm which varied from 6.1 to 8.7 per plant (table 4.12). Lowest population was observed in germplasm Indira Lal and 2015COPB/VAR-5 with 6.1 per plant which was found at par with 2015COPB/VAR-2, 2015COPB/VAR-3, 2015COPB/VAR-6, 2014COPB/VAR-4, 2014COPB/VAR-5 and Kashi Kanchan with 6.3, 6.8, 6.8, 6.7, 7.0 and 7.3 per plant and followed by Lola, 2014COPB/VAR-1, 2014COPB/VAR-2, 2014COPB/VAR-6 and Arka Garima with 7.7, 8.5, 8.7, 8.0 and 7.6 per plant

respectively. Whereas, highest population was recorded in 2014COPB/VAR-2 with 8.7 per plant.

The mean population of pod sucking bug showed singnificant differences among the tested germplasm which varied from 4.1 to 8.6 per plant (table 4.12). Lowest population was observed in germplasm 2015COPB/VAR-3 with 4.1 per plant which is at par with 2015COPB/VAR-2, 2015COPB/VAR-6, Lola with 4.7, 4.2, and 4.6 per plant and followed by Indira lal, 2015COPB/VAR-5, 2014COPB/VAR-1, 2014COPB/VAR-2, 2014COPB/VAR-4, 2014COPB/VAR-5, kasha Kanchan and Arka Garima with 5.8, 5.5, 5.2, 5.1, 6.1, 7.4, 5.9 and 6.9 per plant respectively. Whereas, highest population was recorded in 2014COPB/VAR-6 with 8.6 per plant.

The mean population of flower thrips showed singnificant differences among the tested germplasm which varied from 4.9 to 14.6 per plant (table 4.12). Lowest population was observed in germplasm 2014COPB/VAR-5 and Arka Garima with 4.9 per plant which is at par with 2014COPB/VAR-2, 2014COPB/VAR-4 with 6.3 and 5.9 per plant and followed by 2015COPB/VAR-5, 2015COPB/VAR-3, Indira lal, 2015COPB/VAR-5, Lola, 2014COPB/VAR-1, 2014COPB/VAR-5, 2014COPB/VAR-6 and Kashi Kanchan with 10.9, 13.1, 7.6, 8.7, 12.1, 9.4, 10.5 and 7.3 per plant respectively. Whereas, highest population was recorded in 2015COPB/VAR-6 with 14.6 per plant.

The grain yield among different test germplasm ranged from 52.25 to 162.37 q/ha. The highest yield was recorded with genotypes 2015/COPBVAR-6 (162.37 q/ha) while the lowest yield was recorded with genotypes 2015/COPBVAR-5 (52.25 q/ha) followed by 2015/COPBVAR-3, INDIRA LAL and 2014/COPBVAR-4 (66.77, 71.31 and 73.31 q/ha) respectively.

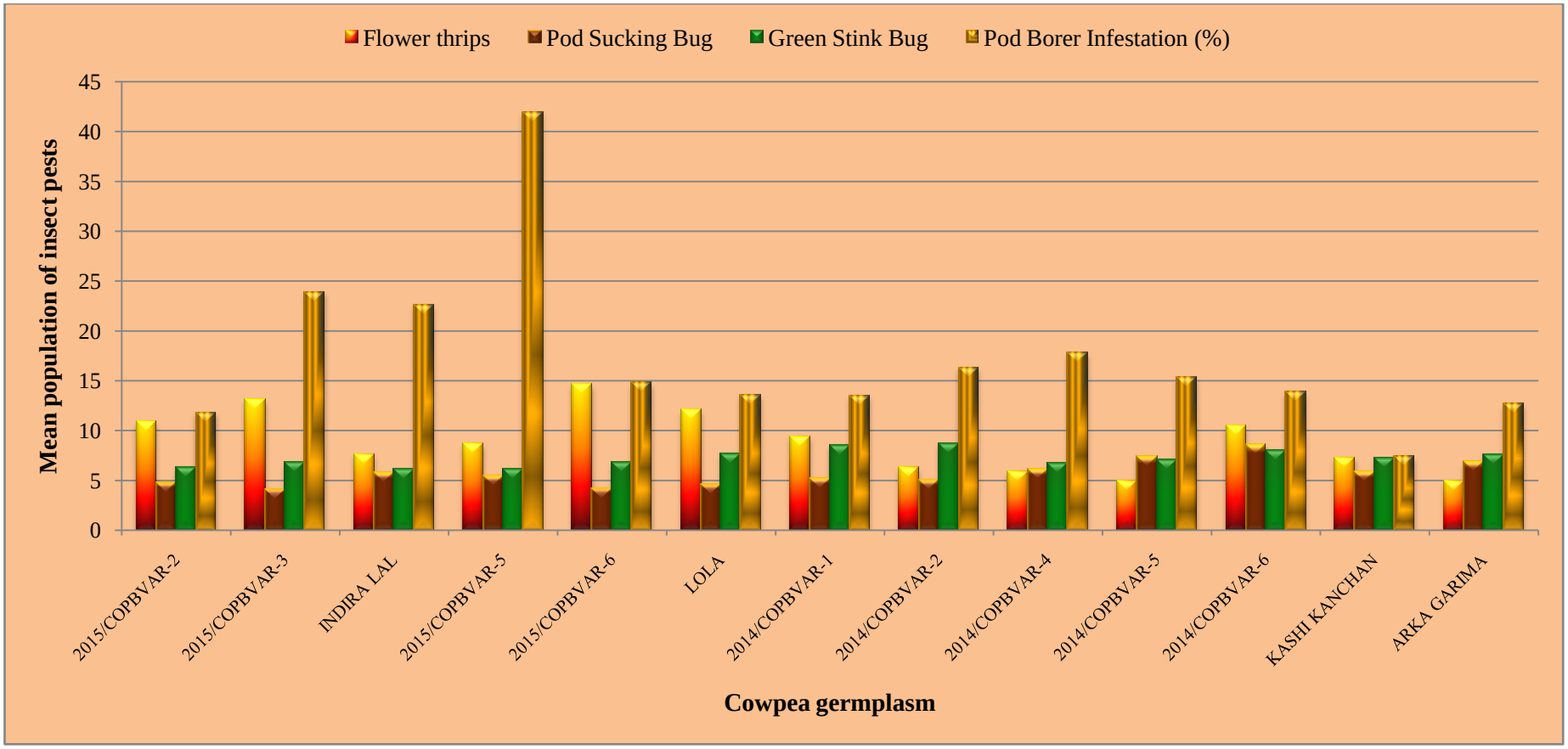


Fig. 4.13: Overall mean population of major insect pests on different cowpea germplasm

4.3: Biochemical analysis of plant parts related to resistance against major insect pests on cowpea germplasm

All thirteen germplasm were selected for the analysis of total phenol and total sugar content from the categories based on per cent pod borer infestation (Table 4.14). The highly resistance germplasm i.e. 2015/COPBVAR-2, 2015/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-2, 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, KASHI KANCHAN, LOLA, ARKA GARIMA and moderately resistance germplasm i.e. 2015/COPBVAR-3, 2015/COPBVAR-4 and INDIRA LAL and intermediate germplasm i.e. 2015/COPBVAR-5 were selected.

Table 4.14:Total phenol and total sugar content on pods of cowpea germplasm

Germplasm	Overall mean of pod borer infestation (%)	Total phenol (mg/g)	Total sugar (mg/g)
2015/ COPBVAR-2	11.84	20.28	3.66
2015/ COPBVAR-3	23.91	12.15	9.64
INDIRA LAL	22.66	10.55	9.32
2015/ COPBVAR-5	41.91	9.68	10.56
2015/ COPBVAR-6	14.86	17.08	5.68
LOLA	13.66	21.10	5.38
2014/ COBVAR-1	13.59	19.41	5.25
2014/ COBVAR-2	16.39	18.82	7.65
2014/ COBVAR-4	17.83	19.57	8.62
2014/ COBVAR-5	15.34	18.52	6.58
2014/ COBVAR-6	13.94	15.50	5.98
Kashi Kanchan	7.45	18.25	3.28
Arka Garima	12.74	20.35	4.68
Correlation coefficient (r)		**-0.794****	**0.851****

***Significant at 5% level**

****Highly significant at 1% level**

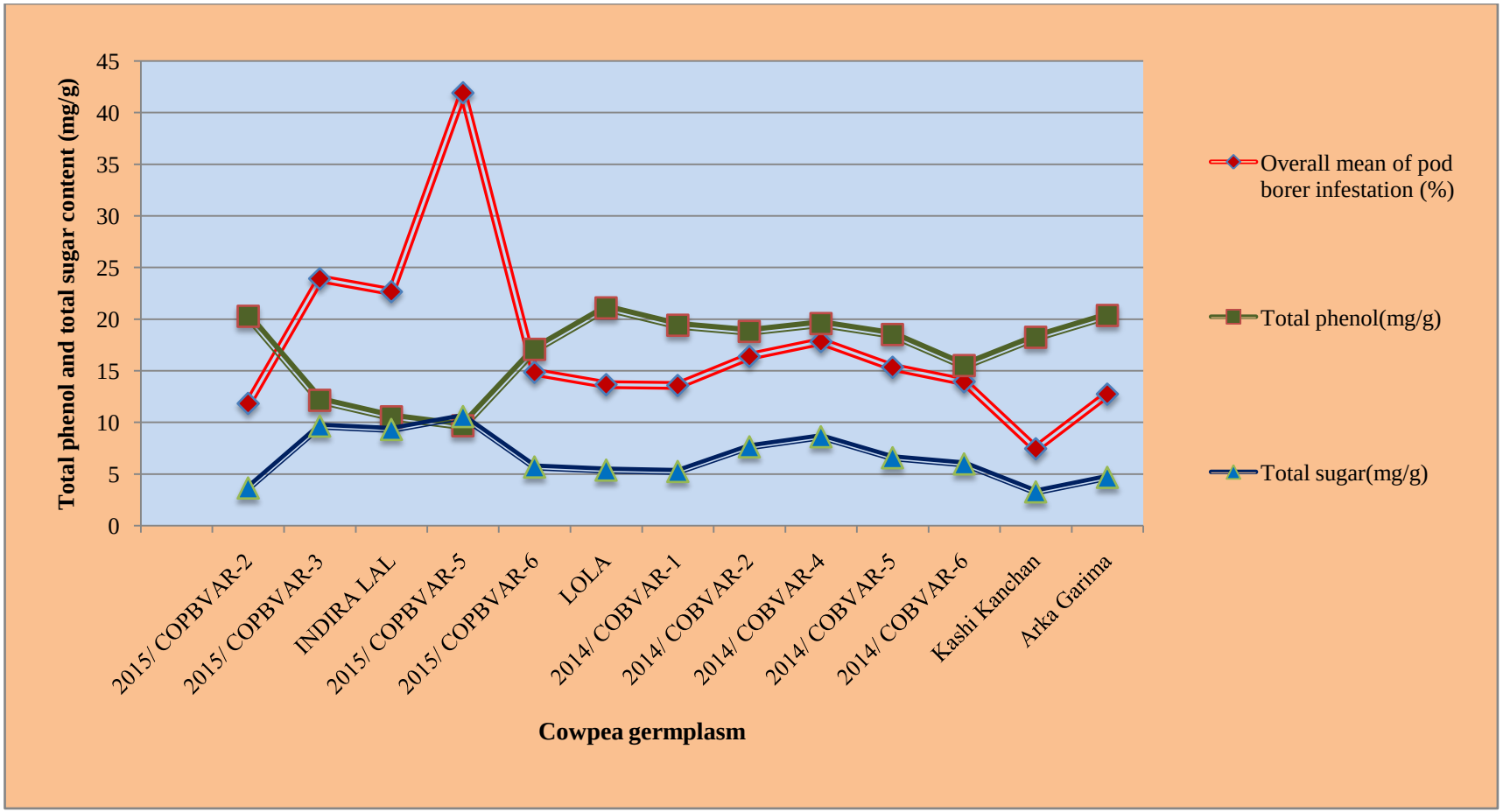


Fig. 4.17: Spotted pod borer infestation corresponding to total phenol and total sugar content of cowpea germplasm

The results presented in table 4.14 and figure 4.17, it was clear that the maximum content of total phenol i.e. 21.10 mg/ g was recorded in Lola followed by 20.35 mg/g in Arka Garima and 20.28 mg/g in 2015/ COPBVAR-3 and 19.41 mg/g in 2014/ COBVAR-1. The mean per cent of spotted pod borer infestation recorded on 2015/ COPBVAR-2, 2014/ COBVAR-4 and 2014/ COBVAR-1 was 11.84, 12.74 and 13.59 per cent respectively. The minimum total phenol content of 9.68 mg/g was recorded in 2015/ COPBVAR-5 (41.91%) followed by 10.55 mg/g in Indira lal (22.66%) and 12.15 mg/g in 2015/ COPBVAR-3 (23.91 %).

A strong negative correlation was observed between the cowpea spotted pod borer infestation and total phenol content (r = – 0.794). Similarly, Singh and Singh (2014), revealed that phenol concentration showed significant negative correlation with percent pod damage.

In case of total sugar content, the lowest sugar content of 3.28 mg/g was found in Kashi kanchan followed by 3.66 mg/g in 2015/ COPBVAR-2 while the highest sugar content of 10.56 mg/g was found in 2015/COPBVAR-5 followed by 9.64 mg/g in 2015/ COPBVAR-3. The mean per cent of cowpea spotted pod borer infestation recorded on Kashi kanchan was 7.45 and 2015/COPBVAR-5 was 41.91 per cent respectively.

A strong positive correlation between total sugar content and pest infestation was noticed (r = 0.851) (Table 4.14). Similarly, Singh and Singh (2014) found that amount of carbohydrate affects significant positively during both the cropping seasons.

Halder *et al.* (2006) observed the relation between total sugar and pod damage was positive and significant. These observations are in agreement with the findings of Macfoy *et al*. (1983), who corroborated that low soluble sugar content (9.01 mg/g) in tolerant cultivar as compared to susceptible Vita-1 (10.50 mg/g).

Sahoo and Senapati (2001) reported that low sugar content (3.23%) on tolerant pigeonpea cultivar S-46 than susceptible ICPL-1 (4.87%) against *M. testulalis*. Significant differences in phenol contents or different genotypes of mung bean (20.00 to 21.03 mg/g) were noticed.

CHAPTER - V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH WORK

The present investigation entitled **"Biophysical and biochemical evaluation of cowpea germplasm against major insect pests"** was conducted in *Kharif,* 2015 and the results are summarized below:

During the course of study, four species of insect-pests *viz*., flower thrips **(***Megalothrips sjoestdi.),* pod sucking bug (*Riptorsus dentipes),* green stink bug (*Nezara viridula)* and spotted pod borer (*Maruca vitrata)* were recorded as the major pest on cowpea. In cowpea germplasm flower thrips, pod sucking bug and green stink bug made their first appearance on the crop in third week of September (39^{th} SMW) and also cowpea pod borer infestation started from third week of September (39^{th} SMW). The overall mean population of flower thrips ranged between 1.5 and 4.3 per plant. The density of flower thrips increased gradually and their peak activity was observed during first week of October (40^{th} SMW). The pod sucking bugs were active throughout the crop season with the range between 0.5 and 9.0 bugs per plant. The maximum population of pod sucking was noticed during second week of November (45^{th} SMW). The population of green stink bug ranged between 0.5 and 12.3 bugs per plant. During second week of November (45^{th} SMW), the maximum population of bugs was noticed. The activity of spotted pod borer increased gradually with peak pod infestation of 19.7 per cent during third week of October (42^{th} SMW). During the crop season, the seasonal mean of flower thrips, pod sucking bug, green stink bug and spotted pod borer infestation was 2.4 per plant, 4.6 per plant, 7.7 per plant and 13.6 per cent, respectively.

Natural enemies *viz.,* lady bird beetle and spider made their first appearance on the crop in third week of September (39^{th} SMW). The density of lady bird beetle and spiders increased gradually with peak population of 1.5 beetles per plant during fourth week of November (48^{th} SMW) and 1.6 spiders per plant during fourth week of October (44^{th} SMW). The seasonal mean of 0.7 beetles per plant

and 1.1 spiders per plant was noticed during the crop season. The population of lady bird beetle showed negatively non significant correlation with population of flower thrips (r = -0.501) and spotted pod borer infestation whereas the population of spider showed positively non significant relation with pod sucking bug (r = 0.001) and green stink bug (r = 0.013) while negatively non significant with spotted pod borer infestation (r= - 0.095).

From the screening of flower thrips, pod sucking bug and green stink bug, it was found that the minimum population of 4.9 thrips per plant was observed in Arka Garima and 2014/COPBVAR-5, whereas, maximum population of 14.6 per plant was observed in 2015/COPBVAR-6. The maximum population of 8.6 pod sucking bug per plant was recorded in 2014/COPBVAR-6 while the least population of 4.1 pod sucking bug per plant was found in 2015/COPBVAR-3. The minimum population of 6.1 green stink bug per plant was observed in 2015/COPBVAR-5 and Indira lal, whereas, the maximum population of 8.7 green stink bug per plant was recorded in 2014/COPBVAR-2.

Among the thirteen germplasm, on the basis of overall mean per cent of pod infestation, ten germplasm were found to be highly resistance (0-20%) and two as moderately resistance (21-40%), whereas, only one germplasm, 2015/ COPBVAR-5 were found as intermediate reaction (41-60%). Highly susceptible (81-100%) and susceptible (61-80%) reaction against cowpea spotted pod borer was not exhibited by any germplasm.

The population of flower thrips was positive highly significant correlated with maximum temperature (r = 0.705), minimum temperature (r = 0.839), positive non significant with maximum (r = 0.182) and positively significant with evening (r = 0.565) relative humidity and negative non significant with rainfall (r = – 0.390) while positive and non significant with sunshine hours (r = 0.369).

The pod sucking bug population had negatively non significant relation with maximum temperature(r= -0.147) and negatively significant relation with minimum (r = -0.598) temperature (at 5%), positive non significant with maximum (r = 0.359), and negative highly significant with evening (r = – 0.771) relative

humidity while negative non significant with rainfall (r = – 0.241) and positively non significant with sunshine hours (r = 0.330).

The population of green stink bug had negative and non significant relation with maximum (r = – 0.194) and negatively significant with minimum (r = – 0.520) temperature, positive non significant with maximum (r = 0.003) and negative significant with evening (r = – 0.620) relative humidity while negatively non significant with rainfall (r = – 0.316) and positively non significant with sunshine hours (r = 0.314).

The spotted borer infestation due to *Maruca vitrata* had positively non significant relation with maximum (r = 0.490), minimum (r = 0.405) temperature, maximum (r = 0.152) and non significant with evening (r = 0.127) relative humidity, sunshine hours (r = 0.023) rainfall (r = 0.178).

From the study of pod parameters of cowpea germplasm, the maximum pod length of 94.25 cm in 2015/ COPBVAR-5 while the smallest pod of 20.35cm was found in Arka Garima. The maximum pod width 3.11cm was recorded on Arka Garima while the minimum pod width 1.94 cm length was recorded on 2015/ COPBVAR-3. The maximum pod weight of 23.65g on 2015/ COPBVAR-5 while lowest pod weight of 6.25g were recorded on 2014/ COBVAR-4. The least number of 9.09 fruits per plant on 2015/ COPBVAR-5 and maximum 29.59 fruits per plant was found on Arka Garima. The positive correlation was found between per cent pod borer infestation and pod length (r = 0.849) and fruit weight (r = 0.628), whereas, negative correlation was found with number of pods per plant (r = – 0.715) and pod width (r= - 0.153).

In case of biochemical analysis, maximum content of total phenol i.e. maximum content of total phenol i.e. 21.10 mg/ g was recorded in Lola and 9.68mg/g lowest phenol content found in 2015/ COPBVAR-5. A strong negative correlation was observed between the cowpea spotted pod borer infestation and total phenol content (r = – 0.794). The lowest sugar content of 3.28 mg/g was found in Kashi kanchan and the highest sugar content of 10.56 mg/g was found in

2015/COPBVAR-5. A strong positive correlation between total sugar content and pest infestation was noticed (r = 0.851).

Conclusion

From the results, it is concluded that

- During the crop season, the seasonal mean of flower thrips, pod sucking bug, green stink bug and spotted pod borer infestation were 2.4 per three leaves, 4.6 per plant, 7.7 per plant and 13.6 per cent, respectively.

- The natural enemies, lady bird beetle and spider coincided with the appearance of host insects on the crop and were active throughout the growth period of the crop. The seasonal mean of 0.7 beetles per plant and 1.1 spiders per plant was noticed during the crop season.

- The results of screening the cowpea germplasm against tested insect pests i.e. spotted pod borer showed that among the thirteen germplasm, 2015/COPBVAR-2, 2015/COPBVAR-6, 2014/COPBVAR-1, 2014/COPBVAR-2, 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, KASHI KANCHAN, LOLA, ARKA GARIMA were least preferred by insect pest while 2015/COPBVAR-3, 2015/COPBVAR-4 found moderately resistance for the insect pest.

- The population of flower thrips was positively related with maximum and minimum temperature, maximum and evening relative humidity and sunshine hours, while negatively related with rainfall. The pod sucking bug and green stink bug showed positive correlation with morning relative humidity and sunshine while negative correlation with maximum temperature, evening relative humidity and rainfall. The spotted pod borer infestation was positively related with all the weather parameters.

- The per cent spotted pod borer infestation showed positive relation with plant height at 70 DAS. The positive correlation was found between pest infestation and pod length and pod weight, whereas, negative correlation

was found with number of pods per plant and pod width. A strong negative correlation was observed between the pest infestation and total phenol content, whereas, strong positive correlation was observed between pest infestation and total sugar content.

Suggestions for future work:-

In future, further following studies should be done-

- Anatomical characters in relation to resistance against spotted pod borer should be identified.

- Major insect pests and its natural enemies on cow pea should be studied on different cropping system and season.

- Life table studies of different insect pest of cowpea crop should be carried out. Study of physiological and biochemical factors such as total chlorophyll, moisture content, ash content conferring resistance against spotted pod borer should be analyzed.

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Appendix I: Status of flower thrips on cowpea germplasm

Germplasm	Population of flower thrips/five flowers/plant at different standard meteorological week(SMW)												
	39 SMW	40 SMW	41 SMW	42 SMW	43 SMW	44 SMW	45 SMW	46 SMW	47 SMW	48 SMW	49 SMW	50 SMW	MEAN
2015/ COPBVAR-2	14.3	15.5	8.3	9.3	13.5	13.0	12.0	11.0	11.8	10.3	6.8	5.0	10.9
2015/ COPBVAR-3	19.3	11.0	11.5	12.5	12.3	14.8	15.0	15.3	15.0	11.8	13.5	5.5	13.1
INDIRA LAL	1.8	8.5	11.8	9.5	0.8	10.5	12.0	5.5	8.0	10.0	7.5	5.8	7.6
2015/ COPBVAR-5	17.3	2.5	4.5	15.5	0.3	8.5	15.0	13.5	7.0	9.5	6.0	5.0	8.7
2015/ COPBVAR-6	26.5	15.7	8.5	14.8	14.8	17.0	17.3	14.8	17.8	10.8	11.0	6.0	14.6
LOLA	20.5	20.0	10.3	15.0	13.5	11.3	11.5	11.0	10.0	10.5	7.5	6.3	12.1
2014/ COBVAR-1	0.0	0.0	1.8	12.3	21.0	19.8	11.0	8.8	15.8	9.8	8.5	3.3	9.4
2014/ COBVAR-2	0.0	0.0	0.0	7.8	5.3	6.0	11.5	11.0	7.0	11.0	10.8	4.0	6.3
2014/ COBVAR-4	0.0	0.0	1.0	9.5	10.3	6.8	9.3	10.5	7.3	8.8	6.5	2.5	5.9
2014/ COBVAR-5	0.0	0.0	0.0	8.8	6.8	4.5	7.3	9.3	4.8	5.8	8.0	4.0	4.9
2014/ COBVAR-6	0.0	0.0	4.0	7.8	21.5	14.3	12.3	13.3	17.0	12.5	9.5	4.0	10.5
Kashi Kanchan	0.0	0.0	0.8	10.3	15.0	10.5	10.8	10.0	11.0	9.8	6.8	1.8	7.3
Arka Garima	0.0	0.0	0.3	9.8	9.0	7.5	5.3	7.3	5.5	5.3	3.8	3.8	4.9

Appendix II: Status of green stink bug on cowpea germplasm

Germplasm	Population of stink bug/plant at different standard meteorological week(SMW)												
	39 SMW	40 SMW	41 SMW	42 SMW	43 SMW	44 SMW	45 SMW	46 SMW	47 SMW	48 SMW	49 SMW	50 SMW	MEAN
2015/COPBVAR-2	1.8	10.3	6.5	8.3	4.5	5.8	6.3	8.3	7.3	7.0	6.3	3.5	6.3
2015/COPBVAR-3	1.3	7.0	5.5	6.8	4.5	6.3	10.0	10.5	9.0	5.8	8.8	6.3	6.8
INDIRA LAL	1.3	3.3	6.3	4.5	2.0	7.8	11.5	12.5	3.8	2.0	9.3	8.8	6.1
2015/COPBVAR-5	0.8	2.3	6.3	6.3	3.5	4.0	8.3	13.8	6.8	2.5	10.0	8.8	6.1
2015/COPBVAR-6	1.0	10.8	6.0	5.3	3.8	8.0	8.0	8.3	10.3	8.5	7.0	4.8	6.8
LOLA	0.5	9.3	5.0	8.3	5.8	8.0	12.3	10.5	9.0	7.3	12.3	4.3	7.7
2014/COPBVAR-1	1.0	24.3	11.0	11.3	7.8	7.3	5.5	7.8	7.8	8.0	6.3	4.0	8.5
2014/COPBVAR-2	1.8	22.8	14.3	11.0	7.5	6.3	8.0	8.5	8.3	7.3	5.8	3.0	8.7
2014/COPBVAR-4	1.0	10.0	11.0	9.5	6.5	6.0	7.0	9.3	5.8	5.5	7.0	2.3	6.7
2014/COPBVAR-5	2.8	13.0	9.5	8.5	5.3	5.8	5.8	10.3	7.3	9.3	5.8	1.5	7.0
2014/COPBVAR-6	1.5	7.3	10.3	11.3	8.0	10.3	5.5	10.3	12.3	12.8	3.8	2.8	8.0
KASHI KANCHAN	2.3	16.3	11.8	9.0	6.3	6.3	3.0	9.3	9.0	7.5	3.5	3.0	7.3
ARKA GARIMA	3.5	10.5	9.8	8.8	6.0	6.5	7.8	11.5	9.0	9.3	6.5	2.8	7.6

Appendix III: Status of pod sucking bug on cowpea germplasm

Germplasm	Population of pod sucking bug/plant at different standard meteorological week(SMW)												
	39 SMW	40 SMW	41 SMW	42 SMW	43 SMW	44 SMW	45 SMW	46 SMW	47 SMW	48 SMW	49 SMW	50 SMW	MEAN
2015/COPBVAR-2	1.0	3.0	4.0	1.8	6.0	3.3	8.0	9.5	7.3	6.5	4.8	2.5	4.7
2015/COPBVAR-3	0.0	4.3	3.8	4.8	5.3	2.0	7.3	4.3	7.5	4.8	4.3	1.0	4.1
INDIRA LAL	2.3	3.5	4.8	4.5	5.0	2.5	6.3	10.5	7.8	6.5	5.0	10.3	5.8
2015/COPBVAR-5	2.8	3.5	4.8	8.3	4.7	2.8	6.8	11.8	5.5	6.5	5.5	5.0	5.5
2015/COPBVAR-6	0.0	2.0	6.0	3.0	4.5	1.5	6.0	8.3	7.5	6.0	4.8	1.3	4.2
LOLA	0.5	3.0	3.8	3.3	3.5	1.5	9.0	7.8	8.8	6.8	4.5	2.5	4.6
2014/COPBVAR-1	0.0	4.5	10.8	7.8	4.3	2.0	6.5	6.5	7.8	6.8	5.0	1.3	5.2
2014/COPBVAR-2	0.0	4.8	10.5	6.3	4.5	3.3	7.8	6.8	7.5	7.0	3.8	1.3	5.1
2014/COPBVAR-4	0.0	1.8	12.0	8.0	8.0	4.0	8.8	5.3	9.8	9.3	6.0	2.5	6.1
2014/COPBVAR-5	4.0	5.0	12.5	9.5	6.3	2.5	9.3	9.5	11.3	9.5	6.0	3.0	7.4
2014/COPBVAR-6	1.0	4.3	12.8	12.8	11.8	6.5	11.8	12.8	13.3	9.5	2.3	0.8	8.6
KASHI KANCHAN	0.0	2.8	12.0	8.5	6.3	3.0	8.0	9.0	8.0	6.5	4.3	2.3	5.9
ARKA GARIMA	0.3	2.5	13.5	10.0	9.5	5.8	9.3	8.5	12.5	6.5	4.8	1.0	6.9

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