STUDIES ON SURVEY, SEASONAL INCIDENCE, VARIETAL SCREENING AND MANAGEMENT OF MAJOR INSECT PESTS OF PIGEONPEA IN THE NORTHERN TRANSITIONAL ZONE OF KARNATAKA

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By

BANDI SANJAY MARUTI

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005

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Chairman:

(L. KRISHNA NAIK)

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INTRODUCTION

The pigeonpea \([\textit{Cajanus cajan} \; (\text{L.}) \; \text{Millsp.}]\), commonly known as Redgram, \(\textit{Tur}, \text{Arhar}\) in India, is an erect and short lived perennial leguminous shrub. It belongs to the genus \(\textit{Cajanus}\) of the sub-tribe \(\textit{Cajaninae}\), tribe \(\textit{Phaseolae}\) of the sub-family \(\textit{Papilionoideae}\) under the family \(\textit{Leguminosae}\). It is evolved in South Asia and appeared about 2000 BC in West Africa, which is considered as a second major center of origin. Pigeonpea constitutes an important ingredient of predominantly Indian vegetarian food. On an average, pigeonpea has 20 to 25 per cent protein on dry seed basis, which is almost 2.5 to 3.0 times of the value normally found in the cereals (Tamboli and Lolage, 2008). It is often consumed as a vegetable (immature pods or green pea) in central India and in contrast in north India, it is eaten as \(\textit{dal}\) (dry split cotyledons). The pod husk and leaves are used as cattle feed and dried stalks as fuel in rural areas. Being a legume, it has ability to resist drought and to add large quantities of biomass to the soil in addition to biological nitrogen fixation.

Pigeonpea is grown worldwide mainly in Southeast Asia, Africa and America over an area of 4 million hectares. India is the world’s largest producer and consumer of pulses including pigeonpea. It is fifth prominent pulse crop in the world and economically it is the second most important pulse crop after chickpea in India accounting for about 12 per cent of total pulse area and 20 per cent of total pulse production of the country (Sharma et al., 2010). About 90 per cent of the global pigeonpea area is in India contributing to 93 per cent of the global production. In India, it is grown on nearly 4.37 million hectares with an annual production of 2.86 million tonnes and average productivity ranges from 600 to 789 kg per hectare. The major pigeonpea growing states are Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Bihar, Uttar Pradesh, etc., contributing 88.20 per cent of total pigeonpea production basket (Anon., 2010). Maharashtra has unique distinction of contributing about 34 per cent of total pigeonpea production in the country. In Karnataka, it is cultivated over an area of 0.89 million hectare with a production of 0.53 million tones and productivity of 596 kg per hectare (Anon., 2012).

The major constraints for low productivity of pigeonpea are inadequate availability of seeds of improved varieties, biotic and abiotic stresses and poor crop management. Of the biotic stresses, the insect pests cause a greater damage with an avoidable losses extending up to 78 per cent in India (Lateef and Reed, 1983). The crop is highly sensitive to attack by a wide range of insect pests both in the fields (at various stages of crop growth) and storage. Most of the pests attack the crop at reproductive stage causing direct losses. More than 250 species of insects belonging to 8 orders and 61 families have been found to attack pigeonpea. Out of the total pests recorded 87.60 per cent of the insect pests belong to three orders, coleoptera, hemiptera and lepidoptera. Rest of the insect pests are spread over in the five orders (diptera, hymenoptera, isoptera, orthoptera and thysanoptera). Of the total insect pests listed to attack the pigeonpea crop, maximum numbers of insect pests (131) are from order hemiptera. Next order on the basis of number of insect pests attack (90) is lepidoptera having the equal number of pests incidence with that of coleopteran. However, only a few of them cause considerable damage to the crop and are economically important as pests. Pod borer (\(\textit{Helicoverpa armigera}\) Hubner), podfly (\(\textit{Melanagromyza obtusa}\) Malloch), legume pod borer/spotted pod borer (\(\textit{Maruca vitrata}\) Geyer), plume moth (\(\textit{Exelastis atomosa}\) May.), blister beetle (\(\textit{Mylabris}\) spp.), pod sucking bugs (\(\textit{Clavigralla}\) spp.) and bruchids (\(\textit{Callosobruchus}\) spp.) are the most important pests, causing damage to the crop (Anon., 2009).

On an average, one third of the pigeonpea produced annually in India is lost due to the insect pest infestation and the estimated monetary value (nearly one million tonnes) is approximately Rs. 15,000 million (Srivastava and Joshi, 2011). The loss in grain yield due to the above said pests damage on pigeonpea was reported to the extent of 20 to 72 per cent (Lateef and Reed, 1983) and the total pod damage due to borer complex has been reported to be 33.80 to 49.90 per cent in India (Lateef and Reed, 1981). The survey undertaken in Marathwada during 2007-08 revealed that the damage by pod fly (\(M. \; \textit{obtusa}\)) ranged from 25.50 to 36.00 per cent (Sharma et al., 2011a). On an average, a single larva of \(H. \; \textit{armigera}\) per plant of pigeonpea could reduce 4.95 green pods, 18.01 grains, 3.79 g pod weight and 2.05 g grain weight per plant (Reed and Lateef, 1990) and could reduce the yield to an extent of 138.50 kg per hectare (Reddy et al., 2001). The loss caused by this pest in pigeonpea has been estimated at 328 million dollars annually in the semi-arid tropics (Sharma et al., 2011b).

Insecticides are still the front line defense and vital component of integrated pest management strategy. Farmers largely relying on use of chemical insecticides for the management of pod borers. This unilateral approach of controlling pest with only insecticides has necessitated the
development of cost effective, eco-friendly and safe management strategy. For better management of these wide arrays of destructive insect pests, the knowledge on their seasonal population fluctuation, natural enemy complex and information on effective biorationals are pre-requisite and successful management of wide array of insect pests requires the integration of several control tactics. The extensive studies of insect pests of pigeonpea have been carried out in traditional pigeonpea growing areas like Gulbarga, Raichur, Bidar and Bijapur. In recent years, the area under pigeonpea in the northern transitional zone of Karnataka comprising of Belgaum, Dharwad, Haveri and Gadag districts is increasing, however barring few studies on bud weevil (Ceuthorrhynchus asperulus Faust.) by Krishna Naik (1979), gall weevil (Alcidodes collaris Pascoe) by Krishna Naik and Lingappa (1995), Giraddi et al. (1999), Hugar (2001) and Balotagi (2004), H. armigera by Bijjur (1990) and Gundanavar (2001), no systematic work has been carried out on pests scenario of pigeonpea in zone eight of Karnataka as the same is differing with respect to intensity and appearance. Hence, in order to devise an effective and economic management strategy against major insect pests of pigeonpea to realize the optimum yield with lesser insecticidal input, the present investigation on “Studies on survey, seasonal incidence, varietal screening and management of major insect pests of pigeonpea in the northern transitional zone of Karnataka” was undertaken with the following objectives.

1) Survey of major insect pests of pigeonpea in the selected districts of northern transitional belt of Karnataka
2) Seasonal abundance of major insect pests of pigeonpea in northern transitional belt of Karnataka
3) Varietal screening to identify the tolerance level of important cultivars
4) Management of insect pests by conventional approach
5) Management of insect pests by biorational approach.
REVIEW OF LITERATURE

The literature on the management of major insect pests of pigeonpea pertaining to the objectives envisaged has been reviewed and presented in this chapter.

2.1 Survey of major insect pests of pigeonpea in the selected districts of northern transitional belt of Karnataka

The incidence of pest complex differs considerably in respect of agro-climatic conditions of the particular region. The faunal make up of the pest diversity is under the control of prevailing physico-chemical conditions. Therefore, the knowledge on the succession of insect pest complex of pigeonpea under the agro-climatic conditions prevailing in transitional belt of Karnataka is prerequisite for developing the effective management strategy.

The major insect pests of pigeonpea in south zone (Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and part of Madhya Pradesh) of India are Maruca vitrata (Geyer), Helicoverpa armigera (Hubner), Lampides boeticus (Linn.) and Grapholita critica (Meyr) on short duration pigeonpea and H. armigera, Melanagromyza obtusa (Malloch) on long duration pigeonpea (Srivastava and Joshi, 2011).

A total of 127 insect species under 113 genera, 59 families and 11 orders were observed in the pigeonpea ecosystem. Amongst the insect orders, coleoptera was the most diverse (31 species) followed by hemiptera (27 species), lepidoptera (19 species), orthoptera (15 species), hymenoptera (14 species), odonata (7 species), dictyoptera (6 species), diptera (4 species), neuroptera (2 species), ephemeroptera and isoptera (1 species each) as observed by Chitra and Soundararajan (2011).

The survey over three years from 2001 to 2003 in Bijapur and Gulbarga districts of Karnataka carried out by Balikai and Yelshetty (2008) revealed that a total of 30 insect pests were found feeding on pigeonpea. Out of these, two pests viz., H. armigera and Aceria cajani Channa. were recorded as major pests by causing more than 51 per cent damage, whereas, eleven insects viz., Megalurothrips usitatus (Bangall), Empoasca kerri Pruthi, Clavigralla gibbosa Spinola, Riptortus pedestris Fb., Exelastis atomosa (Mayr), Melanagromyza obtusa Malloch, Cydia ptychora (Meyr.), Maruca testulalis (Geyer), Etiella zinckenella Treit., Adisura atkinsoni M. and Mylabris pustulata (Thumberg) were recorded as moderate pests by inflicting damage between 31 to 50 per cent. As many as seven insect pests were reported to be minor pests and ten were recorded as negligible pests.

Insect pest scenario of pigeonpea in Northern Karnataka during 2001-03 as per Balikai and Yelshetty (2008) is given in table 1.

The gall weevil, Alcidodes collaris Pascoe was reported as an important pest of pigeonpea in the seedling/vegetative phase of the crop growth in the northern transitional tract of Karnataka (Panchabhavi et al., 1972) and it was a major hindrance in maintaining the plant population causing 25 to 30 per cent reduction in plant population in the field by attacking the basal region of 15 to 30 day aged seedlings resulting in dislodging and drying of plants as noted by Rachappa and Lingappa (2006).

Mandal et al. (2009) identified Odontotermes obesus, Epiosus lacetra, Amrasca sp, M. pustulata, M. testualis, E. atomosa and H. armigera as a major pests and the minor pests were Rhapodopalpa sp, Tricentrus bicolar and Leptocentrus sp. in Indo-gangetic plain.

2.2 Seasonal abundance of major insect pests of pigeonpea in northern transitional belt of Karnataka

The abiotic factors greatly influence the abundance and activity of the pest complex occurring in succession at different reproductive stages of crop in pigeonpea ecosystem. The knowledge of micro-meteorological parameters governing the population buildup of pest complex is vital in understanding the seasonal association of insect pest on pigeonpea and in turn designing the successful management tactics.

2.2.1 Date of sowing

The incidence of M. vitrata was high in late sown conditions at Gulbarga (Gopali et al., 2010). Kabaria et al. (1993) advocated early sowing during the first week of June to avoid pod borer, M. vitrata damage.
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<tr>
<td>Pod sucking bug</td>
<td>Nezara viridula (L.)</td>
<td>Pentatomidae</td>
<td>Flowers, Pods</td>
<td>Negligible</td>
</tr>
<tr>
<td>Brown mottling bug</td>
<td>Dollicoris indicus (Stal.)</td>
<td>Pentatomidae</td>
<td>Flowers, Pods</td>
<td>Negligible</td>
</tr>
<tr>
<td>Pea aphid</td>
<td>Aphis craccivora Koch</td>
<td>Aphididae</td>
<td>Stem</td>
<td>Minor</td>
</tr>
<tr>
<td>Flower thrips</td>
<td>Megalurothrips usitatus (Bangall)</td>
<td>Thripidae</td>
<td>Flowers, Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Jassid</td>
<td>Empoasca kerri Pruthi</td>
<td>Cicadellidae</td>
<td>Leaves</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tur pod bug</td>
<td>Olavigralla gibbosa Spinola</td>
<td>Coreidae</td>
<td>Flowers, Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tur pod bug</td>
<td>Riptortus pedestris Fb.</td>
<td>Coreidae</td>
<td>Flowers, Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Scale insect</td>
<td>Ceroplastodes cajani Masakell</td>
<td>Coccidae</td>
<td>Stem</td>
<td>Minor</td>
</tr>
<tr>
<td>Eriophid mite</td>
<td>Aceria cajani Channa.</td>
<td>Eriophyidae</td>
<td>Leaves</td>
<td>Minor</td>
</tr>
<tr>
<td>Pod borer</td>
<td>Helicoverpa armigera (Hubner)</td>
<td>Noctuidae</td>
<td>Buds, Pods, Flowers</td>
<td>Minor</td>
</tr>
<tr>
<td>Plume moth</td>
<td>Exelastis atomosa (May.)</td>
<td>Pterophoridae</td>
<td>Buds, Pods, Flowers</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tur pod fly</td>
<td>Melanagromyza obtusa Malloch</td>
<td>Agromyzidae</td>
<td>Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Pod borer</td>
<td>Cydia ptychora (Meyr.)</td>
<td>Tortricidae</td>
<td>Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Spotted pod borer</td>
<td>Maruca testulalis (Geyer)</td>
<td>Pyraliidae</td>
<td>Flowers, Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Blue butterfly</td>
<td>Lampides boeticus (Linn.)</td>
<td>Lycaenidae</td>
<td>Buds, Flowers, Pods</td>
<td>Negligible</td>
</tr>
<tr>
<td>Red hairy caterpillar</td>
<td>Amsacta albivaga M.</td>
<td>Arctidae</td>
<td>Leaves, Flower</td>
<td>Minor</td>
</tr>
<tr>
<td>Spiny pod borer</td>
<td>Etella zinckenella Treitschke</td>
<td>Pyralidae</td>
<td>Pods</td>
<td>Moderate</td>
</tr>
<tr>
<td>Field Bean pod borer</td>
<td>Adisura atkinsoni M.</td>
<td>Noctuidae</td>
<td>Buds, Flowers</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tussock caterpillar</td>
<td>Euproctis subnotata Wik.</td>
<td>Lymantridae</td>
<td>Leaves, Buds, Flowers</td>
<td>Minor</td>
</tr>
<tr>
<td>Leaf miner</td>
<td>Aproaerema modicella Devanter</td>
<td>Gelechiidae</td>
<td>Leaves</td>
<td>Negligible</td>
</tr>
<tr>
<td>Ash weevils</td>
<td>Mylocerus discolor F.</td>
<td>Curculionidae</td>
<td>Stem, Leaves</td>
<td>Negligible</td>
</tr>
<tr>
<td>Leaf-cutter bees</td>
<td>Megachile anthracina S.</td>
<td>Megachiliidae</td>
<td>Leaves</td>
<td>Negligible</td>
</tr>
<tr>
<td>Pod weevil</td>
<td>Apion benignum (Faust)</td>
<td>Apionidae</td>
<td>Flowers, Buds</td>
<td>Negligible</td>
</tr>
<tr>
<td>Gall weevil</td>
<td>Alcidodes collaris Pascoe</td>
<td>Curculionidae</td>
<td>Stem</td>
<td>Minor</td>
</tr>
<tr>
<td>Bud weevil</td>
<td>Ceuthorhynchus asperulus Faust.</td>
<td>Curculionidae</td>
<td>Flowers, Buds</td>
<td>Minor</td>
</tr>
<tr>
<td>Blister beetle</td>
<td>Mylabris pustulata (Thumberg)</td>
<td>Meloidae</td>
<td>Flowers</td>
<td>Moderate</td>
</tr>
<tr>
<td>Pulse beetle</td>
<td>Callosobruchus chinensis Linn.</td>
<td>Bruchidae</td>
<td>Pod</td>
<td>Minor</td>
</tr>
<tr>
<td>Leaf roller</td>
<td>Caloptilia soyella D.</td>
<td>Gracillariidae</td>
<td>Leaves</td>
<td>Negligible</td>
</tr>
</tbody>
</table>
The early sown (15th July) pigeonpea variety, ICPL-87 recorded lowest pod damage by *H. armigera* (3.13 %), *E. atomosa* (6.56 %), and *M. obtusa* (10.06 %) as against the late sown crop (30th August) (7.63, 29.88 and 20.15 %, respectively) at Sardarkrushinagar in Gujarat (Nimse and Jat, 2010). Similarly, Prasad *et al.* (1986) reported that pod damage due to pod borer complex was significantly lower (2.60 %) when crop was sown on 10th July and was highest (48.31 %) on crop sown during 25th September.

The reduced pod borer (*H. armigera, M. vitrata, E. atomosa* and *L. boeticus*), pod fly (*M. obtusa*) and pod wasp (*Tanaostigmodes cajaninae* Lasalle) damage was reported by Gajendran *et al.* (2006) on early sown pigeonpea as compared to the farmers practice (late sowing at 3rd week of July) at Pudukkotai in Tamil Nadu.

The early-sown (first week of May) short-duration pigeonpea variety, Manak had less than 6.50 per cent pod damage by *H. armigera* whereas, pod damage to pigeonpea sown in mid-May (15-25th) and mid-June (15-25th) was 26.50 and 39.00 per cent, respectively. Grain yield decreased with a delay in sowing from 1.60 t/ha with early sowing to 1.00 t/ha with late sowing during mid-June at Sonipat in Haryana (Dahiya *et al.*, 1999).

### 2.2.2 Seasonal incidence

Subharani and Singh (2009) opined that the pod borer complex in pigeonpea had a definite successional trend with *L. boeticus* appearing first in the early flowering stage followed by *Cydia ptychora, E. atomosa* and *M. obtusa* which continued till crop maturity. Thus, the crop remained vulnerable to pod borer complex from second week of January to third week of February.

The pod borers, *H. armigera* and *M. obtusa* caused serious damage in semi-arid tropics while under the humid tropical environment *M. vitrata* was the major yield reducer (Saxena *et al.*, 2002).

The incidence of *H. armigera* was particularly severe in south and central India on medium maturing cultivars (Sharma *et al.*, 2001). Akhauri *et al.* (1994) observed the incidence of *H. armigera* between mid-October and end of November with the peak at the end of November at Dholi in Bihar.

The incidence of pod borer complex (pod fly, pod bug and legume pod borer) was recorded in second week of January i.e. 150-160 days after sowing at Varanasi in Uttar Pradesh (Jaiswal *et al.*, 2010).

The temporal population distribution of pod bug, *C. gibbosa* (Spinola) was maximum on 18th December and minimum on 1st January while pod fly, *M. obtusa* was maximum on 1st January and minimum on 18th December at Varanasi as observed by Akhilesh Kumar and Nath (2003a).

The activity of *H. armigera* moth was present in good number during whole of the March month and till the middle of the April at Faizabad in Uttar Pradesh, which suggested that the management should be done during this period only (Singh *et al.*, 2003).

Gopali *et al.* (2010) noticed that the incidence of *M. vitrata* was bimodal where early infestation starts from September reaching its first peak during middle of October and second peak during December at Gulbarga.

The period of maximum activity of *M. vitrata* was between second and last week of November and the mean population fluctuated around 12.67 to 15.17 larvae per plant at Dholi in Bihar. The damage to flowers was minimum (0.65 %) in the second week of October and increased to maximum level (18.66 %) in the last week of November. The mean level of pod damage gradually increased from 10.46 to 26.50 per cent from third week of October to last week of December (Akhauri and Yadav, 2002).

Bisane *et al.* (2008) noticed the early instar (I-III) larvae of *H. armigera* from 45th SMW till 1st SMW (Standard Meteorological Week) of next year with mean peak population at 49th SMW whereas the late (IV-V) instar larvae appeared from 46th to 1st SMW with peak population in 48th SMW at Akola in Maharashtra.

Rajesh Kumar and Durairaj (2012) recorded the peak emergence of *H. armigera* adults during 51st (8.25 moths/trap/week) and 52nd (8.00 moths) SMW followed by 1st SMW (7.25 moths) at Coimbatore. According to Bhoyar *et al.* (2004) the population of *H. armigera* was observed from 2nd week of October (42nd SMW) to first fortnight of February (7th SMW) with highest peak during the last week of November (48th SMW). The *E. atomosa* was most active from the 2nd week of November (46th
SMW) to 2\textsuperscript{nd} week of February (7\textsuperscript{th} SMW) with peak during last week of December (52\textsuperscript{nd} SMW) at Akola.

The larval population of *H. armigera* was available from third week of August to first week of November and fluctuated from 0.70 to 4.80 larvae per 10 plants. The population gradually increased and the highest population (4.80 larvae/10 plants) was recorded during third week of September at Fatehabad in Haryana. It gradually declined in the last week of September and thereafter remained almost static (Bajya et al., 2010).

Among the pod borer complex the pod fly, *M. obtusa* predominated numerically as well as functionally on pre-rabi season pigeonpea cultivar, Sharad with its peak population (15.60 larvae/plant) in the last week of March, when the crop approached near maturity at Dholi in Bihar (Akhauri et al., 2001b). The peak population of pod fly was observed from 8 to 12 SMW in all genotypes at Varanasi (Jaiswal et al., 2010).

The incidence of *M. obtusa* on long duration pigeonpea, Bahar was first noticed in 2\textsuperscript{nd} SMW and continued till 13\textsuperscript{th} SMW at Varanasi. The highest mean population was recorded at 6\textsuperscript{th} SMW (53.73 maggots) while the lowest of 20.80 maggots at 2\textsuperscript{nd} SMW (Keval and Srivastava, 2011).

Benagi et al. (2004) noticed the activity of *H. armigera* (0.4 eggs/plant) during 39\textsuperscript{th} International Standard Week (ISW) in Sannur and during 43\textsuperscript{rd} ISW (0.85 egg and 0.48 larvae per plant) in Farthabad villages of Gulbarga district of Karnataka. The pest population crossed the economic threshold level during 43\textsuperscript{rd} ISW (3.7 eggs/plant), 48\textsuperscript{th} ISW (1.5 larvae/plant) and during 50\textsuperscript{th} ISW (1.3 larvae/plant) at Sannur and at Farthabad during 47\textsuperscript{th} ISW (2.08 eggs/plant), 49\textsuperscript{th} ISW (1.37 larvae/plant) and 52\textsuperscript{nd} ISW (1.0 larvae/Plant)

The incidence of *M. vitrata* was first recorded around seven weeks after sowing (33\textsuperscript{rd} SMW) and continued till the harvest at ICRISAT. The incidence of *H. armigera* was started with the flowering of pigeonpea cultivars and attained its peak during 15-16 weeks after sowing on short duration pigeonpea and 17-19 weeks after sowing in medium and long duration pigeonpea (Srinivasa Rao et al., 2006).

The incidence of *M. vitrata* in three cultivars viz., LRG 41, TRG 22 and TRG 38 revealed that the infestation started with the onset of flowering in first week of November and remained in the field till crop maturity with a peak activity (17.30 larvae/plant) during first fortnight of December (125 days after sowing) with least pest population (0.65 larvae/plant) during the fourth week of January at Tirupati (Chaitanya et al., 2012).

The first incidence of pod fly was observed by Keval et al. (2010) at 4\textsuperscript{th} SMW (24\textsuperscript{th} January) and remained active till 12\textsuperscript{th} SMW on all the varieties at Varanasi. The peak population of pod fly irrespective of variety was at 9\textsuperscript{th} SMW and thereafter, declined due to maturity of grains.

The population buildup of *H. armigera* showed no correlation with physical factors (Patel and Koshiya, 1999). According to Rajesh Kumar and Durairaj (2012) the emergence of *H armigera* adults had a significant negative association with minimum temperature while, other parameters (maximum temperature, relative humidity, rainfall and rainy days) had no influence on pest activity. The positive correlation between rainfall and incidence of *M. vitrata* has been reported by Sharma and Franzmann (2000).

The population of *E. atomosa* in pigeonpea showed a negative correlation with maximum and minimum temperature and positive correlation with morning relative humidity at Akola (Bhoyar et al., 2004).

In an another attempt, Subharani and Singh (2009) noticed that the pod borers (*C. ptychora, E. atomosa, L. boeticus and M. obtusa*) in pigeonpea showed negative correlation with temperature, relative humidity, rainfall and wind speed except in few cases; however, a positive correlation was established with all the pod borers with sunshine hours at Takyelpat in Imphal.

The larval population of pod fly had non-significant negative correlation with relative humidity and non-significant positive correlation with rainfall, temperature and sunshine hours in 2008-09 at Varanasi (Keval and Srivastava, 2011).

The infestation by pod fly, *M. obtusa* started in December and continued till March at Allahabad. The month of February showed maximum damage reaching an average of 52.41, 54.52 and 53.69 per cent seed damage in 2005-06, 2006-07 and 2007-08, respectively (Ashwani Kumar et al., 2011). According to Meena et al. (2010), medium and late maturing cultivars of pigeonpea were
severely damaged by *M. obtusa* during first week of December till first week of March with a peak larval population in second and fourth week of January, respectively at Varanasi.

Maximum temperature below 30°C and minimum temperature between 8.1-17°C and average relative humidity around 60-70 per cent was conducive for buildup of the *M. obtusa* population and rainfall had adverse effect on the population of maggot at Modipuram in Uttar Pradesh (Yadav et al., 2011). A positive significant correlation was observed with maximum temperature, minimum temperature and sunshine during 2009-10 and 2010-11 at Allahabad (Lall and Ashwani Kumar, 2011). According to Ashwani Kumar et al. (2011) the seed infestation by *M. obtusa* did not seem to be influenced significantly by the environmental factors. Akhauri et al. (1997) found it difficult to establish any logical relationship between population build up of *M. obtusa* and the weather factors in North Bihar. On the contrary, Sahoo (1998) reported negative effect with temperature but positive effect with morning relative humidity in coastal districts of Orissa.

Sharma (1998) opined that the high humidity and low temperatures during the months of November-December were conducive for the buildup of *M. vitrata* population.

2.2.3 Natural enemies

In India, altogether 77 parasitoids of *H. armigera* have been reported on different crops (Manjunath et al., 1985; Bhat et al., 2009).

According to Mishra and Shrivastava (2000), the larval parasitoid *Campoletis chlorideae* Uchida was most predominant natural enemy of *H. armigera* and it was important mortality factor for pod borer.

The larval parasitoids, *C. chlorideae* Uchida, *Apanteles* sp., tachinid fly were also recorded on *H. armigera* in pigeonpea ecosystem by Sujalata Devi et al. (2002).

A potential egg parasitoid, *Telenomus* sp. on *H. armigera* was documented by Manjunath et al. (1970) in India.

Danon et al. (2012) documented the larval parasitoid, *Apanteles taragamae* Viereck on *M. vitrata*. The larval parasitoid *Glyptapanteles* sp. was reported from arctiidae by Gupta et al. (2011) in India.

The predatory bug, *Canthecona furcellata* on spotted pod borer, *M. vitrata* was observed by Nebapure and Agnihotri (2011) during the survey conducted in *kharif* 2008 at Pantnagar. Akhilesh Kumar and Nath (2003b) reported the ladybird beetle, *Cheilomenes sexmaculata* (Fabricius) and green lacewing *Chrysoperla carnea* (Stephens) predators from pigeonpea ecosystem.

The important predatory birds in pigeonpea ecosystem such as black drongo (*Dicrurus macrocercus* (Vieilliot)), green bee eater (*Merops orientalis* (Latham)), mynah (*Acridotheres tristis* (Linnaeus)) and crow (*Corvus splendens* (Vieillot)) were reported by Sujalata Devi et al. (2002), Akhilesh Kumar and Nath (2003b) and Singh et al. (2011).

2.3 Varietal screening to identify the tolerance level of important cultivars

Genetic resistance in plants is one of the most effective and economic means of controlling pests in an eco-friendly way. Resistant plants are the first line defense against pests which can be easily adopted by the farmers with a cheaper cost.

After the introduction of photo-insensitive short duration pigeonpea in recent years, some of the minor pests became major. In southern parts of India, the pod fly and the blister beetle, *Mylabris* sp. were once considered as minor pests but attained major pest status (Durairaj and Ganapathy, 2000). The sucking insects such as mealy bug, *Cocidoxystrix insolitus* Green and scales, *Ceroplastodes cajani* Maskell were also reported as major pests in specific locations (Ganapathy et al., 1994). Of late, severe incidence of a hymenopteran pest (*Tanaostigmodes cajariniae* La Salle) on pigeonpea pods was also recorded in southern parts of India (Durairaj et al., 2003).

With the introduction of short duration genotypes for cultivation, Gopali et al. (2010) was of the opinion that *M. vitrata* emerged as one of the major constraints because of the coincidence of high humidity and moderate temperature in September-October coinciding with the flowering stage of the crop in India.
More than 10,000 germplasm accessions have been screened for pod fly resistance however, Singh and Singh (1990) reported that no definite conclusions could be drawn about the relative susceptibility of pigeonpea genotypes to pod fly damage because of staggered flowering and variation in pod fly abundance over time.

Out of 217 pigeonpea genotypes field screened by Ganapathy (2010), no entry was free from damage however, eight genotypes, viz., ICP 7954, ICP 8392, ICP 8400, ICP 11059, ICX 6484, JA 3, JA5 and SMR 1258/2 were identified as resistant to *M. vitrata*.

The short duration pigeonpea lines, ICPL 88037 and MPG 679 which recorded low damage (10 and 25%) and showed excellent recovery from damage when evaluated for recovery resistance to *M. testulalis* on 1 to 5 scale (Saxena *et al.*, 1995) but according to Srinivasa Rao *et al.* (2006) the short duration pigeonpea cultivars suffered with significantly higher infestation of *M. vitrata*.

The higher raceme damage by *M. vitrata* in early (6.41%) and medium (4.17%) than late (0.91%) maturing varieties of pigeonpea was observed by Sahoo and Senapati (2001).

The variety, ICPL 332 (Abhay) developed and released for resistance/tolerance to *H. armigera* exhibited only moderate level of resistance (Saxena *et al.*, 2003).

The serious lepidopteran borer damage was noticed on the cultivars maturing beyond January (Rizwanabanu *et al.*, 2007). The short duration cultivars which flower during the period of high humidity and moderate temperature in September-October in India are highly congenial for rapid multiplication of *M. vitrata* (Srivastava and Joshi, 2011).

Incidence of spotted pod borer, *M. vitrata* was high in early (140-150 days) and late maturing (190-200 days) varieties, whereas it was moderate in medium duration types (170-180 days). The incidence was high in late sown conditions and also in varieties having clustering type of branching habit (Gopali *et al.*, 2010). Short duration genotype with determinate growth habit, where pods are bunched together at the top of the plant, *i.e.* GC-11-39 was susceptible to *M. vitrata*; whereas medium duration genotypes *i.e.* Gulliyal local, TS3-R, WRP-1 and Maruti (ICP-8863) were resistant registering 1.20 to 3.75 webs per plant. Early maturing varieties suffered with greater damage from *M. vitrata* than the late maturing varieties (Sahoo and Patnaik, 1993). The genotypes with determinate growth habit, where pods are bunched together at the top of the plant were more prone to damage by *M. vitrata* than indeterminate ones (Sharma *et al.*, 1999). Early types that bore compact terminal flower clusters provided the favourable microhabitat for *M. vitrata* (Ganapathy, 2010).

Saxena *et al.* (1995) rated the susceptibility levels of pigeonpea cultivars to *M. testulalis* on 1-9 scale and found that the determinate types recorded a high susceptibility score of 7.09 while the indeterminate types registered a lesser susceptibility score of 5.29 only.

From the visual rating system it was evident that ICPL 98009, ICPL 98013 and ICPL 98014 (indeterminate) were less preferred by *Maruca*, while ICPL 98016 (determinate) was more preferred. Incidence of *M. vitrata* population was significantly higher in ICPL 98016 (1.38 webs and 2.09 larvae/plant at 15 days after flowering-DAF; 1.48 webs and 1.92 larvae/plant at 30 DAF) and lower in ICPL 98013 (1.11 webs and 1.54 larvae/plant at 15 DAF; 1.18 webs and 1.47 larvae/plant at 30 DAF) (Mohapatra and Srivastava, 2002).

Among the short duration pigeonpea genotypes, ICPL 98003 and ICPL 98008 recorded lower pod damage by *M. vitrata* (5.80 and 6.70%) and ICPL 88034 recorded the highest (68.00%) pod damage (Sunitha *et al.*, 2008a).

The germplasm, ICP 2459 and ICP 2155 were categorized as highly resistant on the basis of minimum seed damage of 16.43 and 18.62% per cent, respectively (Mishra *et al.*, 2012). The genotypes, PDA88–2E and PDA89-2E providing the partial resistance to pigeonpea pod fly (*M. obtusa*) have been identified in India (Sharma *et al.*, 2011b). The resistant/tolerant genotype, PDA 88-2E recorded lowest pod fly, *M. obtusa* damage of 9.00 and 11.30 per cent grain damage whereas, the susceptible genotype, Bahar recorded highest per cent grain damage of 25.00 and 30.20 in 2006-07 and 2007-08, respectively (Pandey *et al.*, 2011).

The pod fly was the key pest in late maturing pigeonpea causing 40-75 per cent of crop losses in the states of Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan and Maharashtra (Dar *et al.*, 2005). The long duration pigeonpea, which matures in March or April were heavily damaged by *M. obtusa* (Srivastava and Joshi, 2011).
Srinivasa Rao et al. (2005) noticed the infestation of pod bug, *C. gibbosa* for a short period (6 weeks) on short duration (ICPL 84031) pigeonpea and higher on medium duration (PRO-100) pigeonpea (19.30 Cumulative Pest Units) than long duration (LRG-30) pigeonpea (15.58 CPU) but, Yadav et al. (1988) found no difference in the incidence of this pest on both early and late maturing cultivars of pigeonpea whereas, the blister beetle, *Mylabris* sp. infestation was more (54.29 CPU) on medium duration pigeonpea, moderate (39.96 CPU) on long duration and less (24.29 CPU) on short duration pigeonpea (Srinivasa Rao et al., 2005). According to Yadav et al. (1988) the infestation of *Mylabris* spp. was common to early varieties of pigeonpea.

A number of pigeonpea genotypes have been reported to be resistant to *H. armigera* (Sharma et al., 2001). The incidence and damage of *H. armigera* was particularly severe in the medium-maturity cultivars grown in south-central India. Genotypes with indeterminate growth habit in general suffer less damage than the determinate types (Reed and Lateef, 1990). Several workers reported the serious lepidopteran borer damage on determinate, clustering, early and medium maturing pigeonpea cultivars and cultivars maturing beyond January.

The *H. armigera* females showed moderate levels of preference/non-preference for oviposition towards ICPL 87119 (Asha) whereas, ICPL 87 (Pragati) was highly preferred for oviposition. More eggs were laid on genotypes with yellow flowers than those with pink flowers (Kumari et al., 2006).

In the genotypes, LRG 41 and ICPL 87119 (Asha), Anantharaju and Muthiah (2008) recorded minimum incidence of flower feeder blister beetle (*Mylabris* spp.) under insecticide free field conditions. The damage by *M. vitrata* was more in ICPL 87119 (52 webs per 6 plants) as compared to LRG 41 (13 webs per 6 plants).

According to Anitha Kumari et al. (2010) the medium duration genotype, ICPL 87119 (Asha) having indeterminate type of growth habit flowered in 88 to 124 days after seedling emergence and showed better grain yield potential under borer infestation as compared to that of ICPL 87 (Pragati) and recovery resistance was one of the major factor contributing to high yield under *H. armigera* infestation.

The highest per cent pod damage by *H. armigera*, *E. atomosa* and *M. obtusa* was recorded on long (15.60, 8.90, 19.60 %) and medium duration (13.20, 7.30, 13.40 %) pigeonpea than short duration (10.60, 3.90, 5.40 %) whereas, the damage by *M. vitrata* was more on short duration pigeonpea (16.40 %) than medium (5.30 %) and long duration (3.80 %) pigeonpea varieties, LRG 30 (180 days), PRG 100 (150 days) and ICPL 84031 (130 days), respectively (Srinivasa Rao et al., 2003).

The accession ICPL 87 with determinate type of growth habit attracted *M. vitrata* in large numbers resulting in 90 to 100 per cent pod damage within 75 to 80 days after sowing. On an average, the *Maruca* damage on determinate accessions (ICPL 87) was higher (66–75 %) than that of indeterminate (UPAS 120) accessions (41–50 %) ( Saxena et al., 2002).

The early pigeonpea genotypes, ICPL-83015 and Pusa-6 were relatively less susceptible as against ICPL-151 as observed by Akhauri et al. (2001a) which were found highly prone to the damage by spotted pod borer (*M. testulalis*), pod fly (*M. obtusa*) and pod weevil (*Apion clavipes* Gerst.).

The cultivars, ICC 1151, ICC 11967, ICC 13199 and ICC 13204 consistently recorded low number of *Helicoverpa* larvae than check cultivars, Bahar and C11. The total mean pod damage due to pod borer complex (*H. armigera*, *M. vitrata* and *M. obtusa*) was lowest of 74.70 per cent in ICC 13199 and highest of 97.40 per cent in ICC 7182 whereas, check cultivars, Bahar and C11 recorded with 92.40 to 90.50 per cent, respectively (Ujagir et al., 2005).

The genotype, ICP 13201 recorded the lowest percentage (25.00 % pod damage) of *H. armigera* incidence followed by ICP 13208 (28.00 %) and ICP 13212 (28.00 %) whereas, it was highest in ICP 13209 (69.00 %) followed by ICP 13207 (59.00 %) (Rizwanabanu et al., 2007).

### 2.4 Management of insect pests by conventional approach

The use of insecticides is one of the most practical methods available to the farmers for effective suppression of wide array of insect pest occurring in succession in pigeonpea. More often it forms the only solution to the outbreaks of insect pests.

The evaluation of new molecules for the control of insect pest complex on pigeonpea under the AICRP on pigeonpea has led to the identification of spinosad 45 SC (73 g a.i./ha), flubendiamide
20 WG (50 g a.i./ha), indoxacarb 14.5 SC (0.4 kg/ha), emmamectin benzoate 5 WSG (11 g a.i./ha) and bifenthrin 10 EC (40 g a.i./ha) as a most promising insecticide for the management of major insects pest complex in pigeonpea (Srivastava and Joshi, 2011).

The newer insecticide, spinosad 45 SC (90 g a.i./ha) was most potent insecticide in reducing the larval population (0.29 larvae/plant), pod damage (5.62 %), grain damage (22.85 %) by *H. armigera* and highest grain yield of 1681 kg/ha. It was followed by flubendamide 20 WDG (50 g a.i./ha) recording 0.47 larvae per plant and next promising treatment was indoxacarb 15 SC (21.75 g a.i./ha) with 0.58 larvae per plant in pigeonpea (Tamboli and Lolage, 2008)

According to Bhoyar *et al.* (2004) the treatment spinosad 2.5 SC (25 g a.i./ha) was most promising in terms of least pod and grain damage of 11.80 and 13.51 per cent by pod borer complex (*H. armigera, E. atomosa* and *M. obtusa*) against 28.65 and 41.17 per cent in untreated control, respectively. Patel (2006) also reported the effectiveness of spinosad 45 SC (73 g a.i./ha) and emmamectin benzoate 5 WSG (11g a.i./ha) against *H. armigera*.

The spraying of emamectin benzoate 5 WG (9.5 g a.i./ha) registered lowest number of *H. armigera* larvae (0.48 larvae/plant) and pod damage (2.86 %) and higher grain yield of 876 kg per hectare as observed by Barad *et al.* (2013).

Efforts of Ameta *et al.* (2011) revealed the lowest pod (5.67 and 6.14 %) and flower damage (4.71 and 4.99 %) by *H. armigera* and *M. testulalis* in flubendiamide 480 SC (100 ml/ha) during kharif 2006 and 2007, respectively and it was followed by flubendiamide 480 SC (75 ml/ha) and indoxacarb 14.5 SC (500 ml/ha). flubendiamide 480 SC (100 ml/ha) recorded the highest grain yield of 12.15 and 11.91 q/ha during kharif 2006 and 2007, respectively.

The application of indoxacarb (0.0075 %) gave highest mortality (89 to 96 %) of *H. armigera* and grain yield (1486 kg/ha) followed by spinosad (0.009 %) (86 to 95 % mortality) (1451 kg grain yield/ha) and profenophos + cypermethrin (0.044 %) (85 to 94% mortality) (Babariya *et al.*, 2010).

The spraying of emamectin benzoate 5 SG (11 g a.i./ha) in combination with acetamiprid 20 SP (0.008%) or dimethoate 30 EC (0.007 %) gave higher grain yield of 1399 and 1392 kg/ha and lower grain damage (13.30 and 11.95%) by pod fly in BSMR 853 during 2008-09 and 2009-10, respectively (Sharma *et al.*, 2011b).

According to Dodia *et al.* (2009) spraying of flubendiamide 20 WDG (50 g a.i./ha) was found most effective with 5.98 per cent damage by *H. armigera*, which stood at par with emamectin benzoate 5 SG (11 g a.i./ha) (6.53 %) and spinosad 45 SC (73 g a.i./ha) (7.35 %). The maximum grain yield was recorded with emamectin benzoate (1761 kg/ha) followed by spinosad 45 SC (73 g a.i./ha) (1717 kg/ha), indoxacarb 14.5 SC (50 g a.i./ha) (1598 kg/ha). Maximum monitory return was gained in indoxacarb (ICBR 1: 6.88) followed by flubendiamide (ICBR 1: 4.56), spinosad (ICBR 1: 3.61) and emamectin benzoate (ICBR 1:3.41).

Singh *et al.* (1988) observed that quinalphos (0.5 kg a.i./ha) applied three times at fortnightly intervals was very effective against *M. vitrata* in pigeonpea. According to Sunitha *et al.* (2008b), spinosad 48 SC (0.3 ml/l) caused more than 50 per cent mortality of *M. vitrata* larvae.

Rao *et al.* (2007) reported reduction in larval population of *M. vitrata* by 82 and 72 per cent with spinosad 45 SC (0.4 ml/l) and indoxacarb 14.5 SC (1 ml/l), respectively.

In the management of pod borers complex of redgram, Samiayyan and Gajendran (2009) reported that the IPM package consisting of bird perches (50/ha), hand collection of larvae/beetles, pheromone traps (12/ha), *HaNPV* (1.5 x 10^12 POB/ha), spraying of indoxacarb 14.5 SC (0.75 ml/l) at 50 per cent flowering or endosulfan 35 EC (2 ml/l) or monocrotophos 36 WSC (2 ml/l) at the time of flowering/early pod formation stage recorded minimum cumulative pod borer damage (16.27 to 31.51 %) compared to farmers’ practice (30.56 to 47.50 %) with higher grain yield (655 to 1397 kg/ha) and C:B ratio (1:1.7 to 1:2.5).

The per cent inflorescence and pod damage due to *M. vitrata* was lowest in spinosad 45 SC @ 73 g a.i./ha (4.74 and 17.38%), followed by *Bacillus thuringiensis* @ 1.5 kg/ha (10.52 and 27.57%) and *Beauveria bassiana* SC @ 300 mg/L (14.15 and 33.82%) as observed by Sreekantan and Seshamahalakshmi (2012).

Narasimharmurthy and Keval (2012) noticed the lowest pod damage (16.30%) in spinosad 45 SC (73 g a.i./ha) sprayed plots, followed by indoxocarb 14.5 SC (60 g a.i./ha) with 18.00 per cent pod
damage by pod fly and highest per cent pod damage (39.40 % and 32.90 %) was recorded in the treatment, Beauveria bassiana (1.5 kg/ha) and NSKE (5%).

Srinivasan and Philip Sridhar (2008) reported that the adoption of IPM module consisting of the components viz., intercropping with groundnut, setting up of pheromone traps against H. armigera, erection of bird perches, application of neem seed kernel extract (NSKE), spraying of HaNPV and need based spraying of insecticides registered reduced pod borer damage (31.50-35.67 %), pod wasp damage (3.33-4.67 %), pod fly seed damage (5.00-6.00 %) and pod bug damage (5.67-8.67 %) as against the farmer’s practice of dusting with lindane 1.3D (25 kg/ha) at peak flowering, which recorded higher pod borer damage (48.67-54.67 %), pod wasp damage (6.33-8.33 %), pod fly seed damage (6.66-8.67 %) and pod bug damage (5.66–13.33 %). The grain yield (714 –801 kg/ha) and benefit:cost (2.41–2.79) were also higher in IPM plots compared to farmer’s practice.

Siddhhabhatti et al. (2004) reported that the spraying of profenophos (0.2 %) + NSKE (5%) + endosulfan (0.07 %) + bird perches (1/plot) was found most effective causing maximum larval reduction (58.33 %) and giving highest grain yield (1648 kg/ha) followed by a treatment including Bt (1 kg/ha) + NSKE + endosulfan + bird perches with 57.57 per cent larval reduction and 1540 kg/ha grain yield.

The use of bird perches (50/ha), mechanical collection, use of bio-rational pesticides (neem based at 50% flowering and HaNPV at early pod set) and need based spraying of insecticides at flowering and podding stage against pod borer complex on early sowing of pigeonpea (3rd week of June) registered reduced pod borer (14.6 - 26.6 %), pod wasp (1.8- 3.0 %) and pod fly (2.4- 4.0 %) damage with a grain yield of 362-530 kg/ha and benefit cost ratio of 1.73 to 1.91 (Gajendran et al., 2006).

2.5 Management of insect pests by biorational approach

The exclusive dependence on conventional chemical pesticides is not likely to provide sustained solutions against the pod borer complex because of development of resistance and elimination of natural enemies. The use of biorational insecticides in combination with newer and safer insecticides is, therefore, necessary for sustainability of management system in pigeonpea.

Application of HaNPV (450 LE/ha) was found most effective against H. armigera on 8th and 14th day after spraying and appeared significantly superior over HaNPV (240 LE/ha), Bt (1 %), NSKE (5 %), beta-cyfluthrin (25 g a.i/ha), lambda cyhalothrin (50 g a.i/ha) and endosulfan (0.7 %) on 8th and 14th days after spraying (Yadav, 2009).

Mohapatra and Srivastava (2008) reported that Bacillus thuringiensis provided good protection and registered significantly lesser incidence of M. vitrata larvae and higher yield over control. Manjula and Padmavathamma (1996) reported the effectiveness of microbial insecticides, B. thuringiensis and B. bassiana against M. testulalis in pigeonpea.

The Bacillus thuringiensis var. kurstaki based product (Spic-Bio Reg.) at 2.5 l/ha was the best treatment, recording lesser H. armigera larval population (0.7/plant) over untreated check (Thilagam and Kennedy, 2007).

The two sprays of ecofriendly bio-pesticides (B. thuringiensis, NSKE 5% and nimbecidine) were found significantly superior in reducing the pod damage by pod bug (C. gibbosa). Two spray of NSKE (5 %) (first at flowering and pod formation stage and second 20 days later) inflicted minimum of 11.00 and 9.00 per cent pod damage during 2006 and 2007 crop season, respectively (Singh and Nath, 2011).

According to Sunil Kumar et al. (2009) the adoption of IPM package consisting of fall summer ploughing + sorghum seeds (250 g/ha) as live bird perches + pheromone traps (5/ha) + profenophos 50 EC (2000 ml/ha) + neem 1500 ppm (2000 ml/ha) + HaNPV (250 LE/ha) + indoxacarb 14.5 SC (300 ml/ha) registered lowest H. armigera pod damage of 8.49 per cent as against 12.12 per cent in non-IPM.

Gundannavar et al. (2003) studied the sequential application of pesticides on the basis of cost effectiveness and environmental stability, the sequence comprising of B. thuringiensis, NSKE, endosulfan was found to be most effective schedule than the sequence involving N. rileyi, B. bassiana and NPV (125 LE/ha).

Srinivasa Rao and Dharma Reddy (2003) reported that the sequential application of HaNPV (500 LE/ha)-NSKE (5 %)-endosulfan (0.075 %) with bird perches was found effective against
lepidopteran pod borers and recorded reduced pod (8.30 and 8.30 %) and grain (9.00 and 8.60 %) damage and higher grain yield (11.99 and 12.65 q/ha) during 2000 and 2001 on long duration pigeonpea, LRG-30.

The spraying sequence consisting of azadirachtin 10000 ppm (1 ml/L at 50 % flowering) - emamectin benzoate 5 SG (3 g/10 L at 15 day after first spraying) - deltamethrin 1 EC + triazophos 35 EC ready mix formulation (2.5 ml /L at 15 days after second spraying) registered highest larval reduction of lepidopteran pod borers, lowest pod and seed damage due to pod borer complex over control and incremental cost benefit ratio of 1:5.2 (Wadaskar et al., 2012).

The lower damage by pod borer complex (H. armigera M. vitrata and M. obtusa) was recorded in combination treatments as compared to sole insecticidal treatment. A combination of chlorpyriphos (400 g a.i./ha), NPV (500 LE/ha) and NSKE (5 %) was found most effective with reduced per cent pod damage (9.7 %) and highest grain yield of 1902.20 kg/ha (Bhandari and Ujagir, 2002).

Nath and Singh (2006) noticed the superiority of two sprays of bio-pesticides as against one spray. Two sprays (first at flowering/pod formation stage and second 20 days later) of eco-friendly bio-pesticides (B. thuringiensis, NSKE 5 % and nimbecidine) were found superior over one spray of bio-pesticide in reducing the pigeonpea pod damage, grain damage and grain weight loss due to H. armigera.

Singh et al. (2012) reported that the application of NSKE 5 %, nimbecidine 1 % and B. thuringiensis kurstaki 1.5 % (first at flowering/formation stage and second after 20 days) had significant influence in reducing pod damage (0.6, 1.1 and 1.0 %, respectively) inflicted by plume moth, E atomosa.

Bhoyar et al. (2004) recorded the higher grain yield of 14.43 q/ha from spinosad treated plots of pigeonpea as compared to control plots (7.76 q/ha).

Yadav, 2009 obtained the maximum cost benefit ratio (1:5.13) with higher dose of HaNPV (450 LE/ha). Shantibala and Singh (2008) reported the lowest cost benefit ratio (1:2.40) and 36.70 per cent of avoidable yield loss in the treatment B. thuringiensis kurstaki due to its higher cost than endosulfan 35 EC and cypermethrin 25 EC.

In an another attempt, Yelshetty et al. (2003) noticed the highest benefit-cost ratio of 2.30 in biointensive module (HaNPV 250LE/ha, hand collection, B. thuringiensis (1.00 kg/ha), NSKE 5% followed by HaNPV (250LE/ha) over recommended package of practice (1.76) and showed the superiority of biointensive module during heavy pest load in pigeonpea ecosystem.
MATERIAL AND METHODS

Investigations on “Studies on survey, seasonal incidence, varietal screening and management of major insect pests of pigeonpea in the northern transitional zone of Karnataka” were carried out during 2011-12 and 2012-13 at Main Agriculture Research Station (MARS), Dharwad. Dharwad is situated in the northern transitional region (Zone-8) of Karnataka between 15° 07’ N latitude 76° 06’ E longitude with an altitude of 678 meter above Mean Sea Level (MSL). The details of material used and methodologies followed during the course of study are described as follows:

3.1 Survey of major insect pests of pigeonpea in the selected districts of northern transitional belt of Karnataka

A fixed plot survey was carried out during 2011-12 and 2012-13 in Belgaum, Dharwad and Haveri districts of transitional belt of Karnataka (Plate 1). In each districts two taluks and in each taluk two villages were selected for the study (Table 2). From each village four farmers fields were selected for recording the activity of insect pests on the crop.

3.1.1 Observations

A survey was carried out thrice (pre-flowering, flowering and pod formation stage) during the cropping season. The observation on population density of insect pests was recorded from five randomly selected plants in each field from selected villages.

3.2 Seasonal abundance of major insect pests of pigeonpea in northern transitional belt of Karnataka

The pigeonpea variety, ICP–8863 (Maruti) was raised by staggered sowing at fortnightly interval (June first week, June third week, July first week, July third week and August first week) under unprotected condition in Randomized Block Design with a spacing of 90 cm x 30 cm in a plot size of 5.4 x 4.5 meter to study the effect of dates of sowing on the incidence of insect pest (Plate 2). The treatments were replicated four times. The recommended agronomic practices were followed to raise the crop. The seasonal occurrence of major insect pests against each meteorological week was recorded on the crop sown from third week of June.

Table 2. Details of places surveyed for recording major insect pest of pigeonpea

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>District</th>
<th>Taluk</th>
<th>Villages surveyed</th>
<th>Cropping system</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belgaum</td>
<td>Bailhongal</td>
<td>Jarlikoppa, Budarkatti</td>
<td>Pigeonpea + Sorghum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Savadatti</td>
<td>Hireulligeri, Inamhongal,</td>
<td>Pigeonpea + Cotton</td>
</tr>
<tr>
<td>2</td>
<td>Dharwad</td>
<td>Dharwad</td>
<td>Daddikamalapur, Madihal</td>
<td>Pigeonpea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Navalgund</td>
<td>Navalgund, Amargol</td>
<td>Pigeonpea</td>
</tr>
<tr>
<td>3</td>
<td>Haveri</td>
<td>Byadgi</td>
<td>Shidenur, Guddadamallapur</td>
<td>Pigeonpea + Chilli/Ginger/Banana</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ranebennur</td>
<td>Kakola, Hulihalli</td>
<td>Pigeonpea + Sorghum/Cotton/ Maize</td>
</tr>
</tbody>
</table>
Plate 1: Map showing areas surveyed for insect pests of pigeonpea in the northern transitional zone of Karnataka
3.2.1 Observations

The observations were recorded on five randomly selected and tagged plants. The pest density was correlated with weather parameters (maximum and minimum temperature, relative humidity and rainfall) to assess the impact of various abiotic factors on the incidence of insect pests. The various weather parameters prevailed during the course of experiment were obtained from meteorological observatory, MARS Dharwad and are presented in Appendix-I.

The observations on the incidence of gall weevil and pod feeding insects were expressed by using the formula given below.

3.2.1.1 Gall weevil: \textit{(Alcidodes collaris} Pascoe\textit{)}

\[
\text{Galled plants} \quad \text{Per cent galled plants} = \frac{\text{Galled plants}}{\text{Total plants observed}} \times 100
\]

In each plot, total number of galled and healthy plants at 15, 25, 35 and 45 days after crop emergence was recorded and expressed as percentage of galled plants.

3.2.1.2 Pod feeding insects:

\[
\text{Number of damaged pods} \quad \text{Per cent pod damage} = \frac{\text{Number of damaged pods}}{\text{Total number of pods observed}} \times 100
\]

A total of 100 pods from five randomly selected and tagged plants were plucked at harvest and examined in the laboratory for external and internal damage done by the insects. On the basis of external symptoms as well as type of injury to the grains, the pods were sorted out to four groups to record the damage by \textit{Helicoverpa armigera} (Hubner), \textit{Melanagromyza obtusa} (Malloch), \textit{Exelastis atomosa} (May.) and healthy pods. The per cent pod damage by each pod borer was worked out separately on the basis of damaged pods to total pods observed.

3.2.2 Insect pest scenario

Insect pests collected during the course of investigation were got identified from Agriculture Research Station (ARS), Gulbarga (India).

3.2.3 Parasitoids

Ten late-instar (4 to 6\textsuperscript{th} instar) larvae of lepidopteran pod borer were collected randomly from an unsprayed field of pigeonpea and were reared individually in specimen tubes under laboratory condition. The larvae were reared on freshly collected buds, flowers and pods and food was changed regularly as and when required until the pupation of pest. The parasitoids emerged out of host larvae were collected and got identified from National Bureau of Agriculturally Important Insects (NBAII), Bangalore (India).

3.3 Varietal screening to identify the tolerance level of important cultivars to major insect pests

A field experiment was carried during 2011-12 and 2012-13 in Randomized Block Design (RBD) with ten cultivars, screened under natural conditions (Table 3). Each cultivar was sown in two rows of 6 meter length at spacing of 90×30 cm and replicated thrice. The cultivars were sown during third week of June following the recommended package of practices except the plant protection measures.

3.3.1 Observations

The observations on pest density was recorded on five randomly selected and tagged plants in each cultivar from the first appearance of pests to harvesting stage of the crop at weekly interval. The observations on the incidence of pod feeding insects were recorded and expressed as given in 3.2.1.2.
Plate 2: Field view of pigeonpea experimental plot
### Table 3. Details of pigeonpea cultivars screened against the major insect pests

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Cultivars</th>
<th>Duration in days</th>
<th>Growth habit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICPL-87119 (Asha)</td>
<td>190-220 (LD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>2</td>
<td>ICP-8863 (Maruti)</td>
<td>170-180 (MD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>3</td>
<td>BSMR-736</td>
<td>190-220 (LD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>4</td>
<td>GC-11-39</td>
<td>130-140 (ED)</td>
<td>Determinate</td>
</tr>
<tr>
<td>5</td>
<td>TS-3(R)</td>
<td>150-160 (MD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>6</td>
<td>WRP-1</td>
<td>150-160 (MD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>7</td>
<td>S-1</td>
<td>200-210 (LD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>8</td>
<td>BRG-2</td>
<td>180 (MD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>9</td>
<td>HY-3C</td>
<td>160-180 (MD)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>10</td>
<td>ICPH-2671</td>
<td>165-175 (MD)</td>
<td>Indeterminate</td>
</tr>
</tbody>
</table>

LD = Late duration, ED = Early duration, MD = Medium duration

### Table 4. Treatments employed for the management of major insect pests of pigeonpea by conventional approach

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments with dosage (ml or g per litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bird perches - Hand collection of caterpillars</td>
</tr>
<tr>
<td>2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC ml/l</td>
</tr>
<tr>
<td>3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC ml/l</td>
</tr>
<tr>
<td>4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
</tr>
<tr>
<td>5</td>
<td>Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
</tr>
<tr>
<td>6</td>
<td>DDVP 76 EC (0.5 ml/l) - Bacillus thuringiensis (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
</tr>
<tr>
<td>7</td>
<td>Acephate 75 SP (1 g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
</tr>
<tr>
<td>8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
</tr>
<tr>
<td>9</td>
<td>Untreated check</td>
</tr>
</tbody>
</table>
3.4 Management of insect pests by conventional approach

A field experiment was laid out during 2011-12 and 2012-13 in Randomized Block Design (RBD) with nine treatments including an untreated check. Each treatment was replicated thrice. The variety, ICP – 8863 (Maruti) was sown in plots of 5.4 x 4.5 m size maintaining the spacing of 90 cm between rows and 30 cm from plant to plant. The recommended package of practice was followed except the plant protection measures. The treatment details are presented in table 4.

3.4.1 Spray schedule

Each treatment comprised of three insecticides which were sprayed in sequence. The first insecticide of the treatment was sprayed at flowering stage and subsequent insecticides were sprayed at 15 days interval.

3.4.2 Observations

The observations on larval count were recorded from each plot at a day prior and at three, seven and fourteen days after each spray. The observations on the incidence of pod feeding insects were recorded and expressed as given in 3.2.1.2. The grain yield was recorded at harvest from net plot and computed to hectare basis.

3.5 Management of insect pests by biorational approach

The field trial on management of major insect pests of pigeonpea using biorational insecticides was carried out during 2011-12 and 2012-13 at Main Agricultural Research Station (MARS), Dharwad in a Randomized Block Design (RBD) with nine treatments replicated thrice. The treatment details are given in table 5. The variety, ICP-8863 (Maruti) was sown in plots of 5.4 x 4.5 m size maintaining the spacing of 90 cm between rows and 30 cm from plant to plant. The recommended package of practice was followed except the plant protection measures.

The details of spraying schedule and method of observations are as mentioned in 3.4.1 and 3.4.2

3.6 Statistical analysis

Data collected from field experiments were statistically analyzed using Randomized Block Design (RBD). Square root transformation was followed for converting the population numbers. The per cent data was subjected to angular/arcsine transformation. The treatment means were compared by Duncan’s Multiple Range Test (DMRT) for their significance. The pest density under seasonal incidence was subjected to correlation and regression analysis with weather parameters in respect of the corresponding Meteorological Standard Week (MSW). (Gomez and Gomez, 1985). The results were finally presented in the ensuing chapters and discussed.
Table 5. Treatments employed for the management of major insect pests of pigeonpea by biorational approach

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments with dosage (ml or g per litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - <em>HaNPV</em> (250 LE) - <em>Bacillus thuringiensis</em> (<em>B.t</em>.) (2 kg/ha)</td>
</tr>
<tr>
<td>2</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - <em>Beauveria bassiana</em> (2x10^8 spores/g) (2 g/l) - <em>B.t</em> (2 kg/ha)</td>
</tr>
<tr>
<td>3</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - <em>Nomuraea rileyi</em> (2 x10^8 spores/g) (2 g/l) – <em>B.t.</em> (2 kg/ha)</td>
</tr>
<tr>
<td>4</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - <em>Metarhizium anisopliae</em> (2 x10^8 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
</tr>
<tr>
<td>5</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - <em>HaNPV</em> (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
</tr>
<tr>
<td>6</td>
<td>Nimbecidine 0.03 EC (3 ml/l) – <em>B. bassiana</em> (2x10^8 spores/g) (2 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
</tr>
<tr>
<td>7</td>
<td>Nimbecidine 0.03 EC (3 ml/l) – <em>N. rileyi</em> (2 x10^8 spores) (2 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
</tr>
<tr>
<td>8</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - <em>B. t.</em> (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
</tr>
<tr>
<td>9</td>
<td>Untreated check</td>
</tr>
</tbody>
</table>

**Note:** Inanimate bird perches were erected in treatments from one to eight at the rate of 20 per hectare.
EXPERIMENTAL RESULTS

The results of the investigations on survey, seasonal incidence, varietal screening and management of major insect pests of pigeonpea carried out during 2011-12 and 2012-13 at Main Agricultural Research Station, Dharwad, Karnataka are presented in this chapter.

4.1 Survey of major insect pests of pigeonpea in the selected districts of northern transitional zone

The survey on major insect pests of pigeonpea in Belgaum, Dharwad and Haveri districts of northern transitional zone (Zone-8) of Karnataka was conducted for two years during 2011-12 and 2012-13. The survey was conducted thrice starting first at pre-flowering (vegetative stage), flowering and pod formation stage and average values for each district have been presented in tables 6 to 7.

4.1.1 Belgaum district

At pre-flowering stage

During the first survey carriedout at pre-flowering stage of the crop (2011-12 and 2012-13), the insect pests viz., ash weevil, leaf webber, hairy caterpillar and aphids were observed in Belgaum district.

Among four villages surveyed, the highest population of ash weevil, leaf webber (webs/plant), hairy caterpillar and aphids (0.62, 3.12, 0.41 and 15.13) was recorded in Jarlikoppa, Budarkatti, Hireulligeri and Jarlikoppa, respectively during 2011-12 (Table 6). During 2012-13, the highest population of ash weevil (0.84 weevils/plant) and hairy caterpillars (1.20 larvae/plant) was noticed in Hireulligeri and Budarkatti, respectively. The incidence of leaf webber and aphids was not observed in Belgaum district during 2012-13 (Table 7).

The mean population of ash weevil, leaf webber (webs/plant), hairy caterpillar and aphids in Belgaum district was 0.32, 0.78, 0.16 and 3.78 during 2011-12 and 0.42, 0.00, 0.56 and 0.00 during 2012-13, respectively.

At flowering stage

The insect pests observed during the second survey conducted at flowering stage of the crop in Belgaum district were bud weevil, hairy caterpillar, spotted pod borer and gram pod borer.

Out of four villages surveyed, the maximum population of bud weevil (2.82 weevils/plant) and gram pod borer (1.23 larvae/plant) was recorded in Jarlikoppa and Hireulligeri, respectively whereas; the highest population of hairy caterpillar (2.11 larvae/plant) and spotted pod borer (2.24 webs/plant) was noticed in Budarkatti village during 2011-12 (Table 6). During the year, 2012-13, the Jarlikoppa village recorded highest mean population of bud weevil (3.20 weevils/plant), hairy caterpillar (1.24 larvae/plant) and gram pod borer (2.00 larvae/plant), whereas the mean population of spotted pod borer (1.21 webs/plant) was higher in Hireulligeri (Table 7).

The average population of bud weevil, hairy caterpillar, spotted pod borer (webs/plant) and gram pod borer in Belgaum district was 1.51, 0.53, 0.86 and 0.82 during 2011-12 and 1.67, 0.42, 0.30 and 1.27 during 2012-13, respectively.

At pod formation stage

Bud weevil, pod bugs, gram pod borer, blister beetle and plume moth were found in third survey at pod formation stage during 2011-12 and 2012-13.

The incidence of bud weevil, pod bugs and blister beetle was higher (3.41 weevils/plant, 2.14 bugs/plant and 1.21 beetles/plant) in Jarlikoppa, whereas the population of gram pod borer and plume moth was high (2.43 and 0.44 larvae/plant) in Budarkatti village during 2011-12 (Table 6). Jarlikoppa village recorded higher incidence of bud weevil (4.20 weevils/plant) and plume moth (0.28 larvae/plant) during 2012-13, whereas pod bugs (0.24 bugs/plant) and gram pod borer (2.00 larvae/plant) was higher in Budarkatti and blister beetle (0.80 beetles/plant) in Hireulligeri village (Table 7).

The mean population of bud weevil, pod bugs, gram pod borer, blister beetle and plume moth in Belgaum district was 2.95, 0.54, 1.69, 0.58 and 0.18 during 2011-12 and 2.18, 0.06, 1.23, 0.26 and 0.12 during 2012-13, respectively.
Table 6: Insect pests encountered during the survey on pigeonpea in the farmers fields of Belgaum, Dharwad and Haveri during 2011-12

<table>
<thead>
<tr>
<th>District</th>
<th>Taluk</th>
<th>Villages</th>
<th>At pre-flowering stage</th>
<th>At flowering stage</th>
<th>At pod formation stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Aw</em></td>
<td>#Lw</td>
<td>*Hc</td>
</tr>
<tr>
<td>Belgaum</td>
<td>Bailhongal</td>
<td>Jarlikoppa</td>
<td>0.62</td>
<td>0.00</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Budarkatti</td>
<td>0.41</td>
<td>3.12</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Savadatti</td>
<td>Hireulligeri</td>
<td>0.00</td>
<td>0.00</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inamhongal</td>
<td>0.26</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>0.32</strong></td>
<td><strong>0.78</strong></td>
<td><strong>0.16</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dharwad</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dharwad</td>
<td>Daddikamalapur</td>
<td>1.42</td>
<td>3.44</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Madihal</td>
<td>0.86</td>
<td>0.00</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Navalgund</td>
<td>0.42</td>
<td>0.00</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amargol</td>
<td>1.10</td>
<td>3.87</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>0.95</strong></td>
<td><strong>1.83</strong></td>
<td><strong>0.71</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Haveri</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Byadgi</td>
<td>Shidenur</td>
<td>1.61</td>
<td>4.23</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Guddadamalapur</td>
<td>1.44</td>
<td>4.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kakola</td>
<td>1.82</td>
<td>3.81</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hulihalli</td>
<td>1.22</td>
<td>2.84</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>1.52</strong></td>
<td><strong>3.72</strong></td>
<td><strong>1.01</strong></td>
</tr>
</tbody>
</table>


* Number of insects per plant, ** Number of insects on top 15 cm twig, # Number of webs per plant
Table 7: Insect pests encountered during the survey on pigeonpea in the farmers fields of Belgaum, Dharwad and Haveri during 2012-13

<table>
<thead>
<tr>
<th>District</th>
<th>Taluk</th>
<th>Villages</th>
<th>At pre-flowering stage</th>
<th>At flowering stage</th>
<th>At pod formation stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>*Aw # Lw *Hc **Ap</td>
<td>*Bw *Hc #Spb *Gpb</td>
<td>*Bw *Pb *Gpb *Bb *Pm</td>
</tr>
<tr>
<td>Belgaum</td>
<td>Bailhongal</td>
<td>Jarlikoppa</td>
<td>0.20 0.00 0.82 0.00</td>
<td>3.20 1.24 0.00 2.00</td>
<td>4.20 0.00 0.84 0.24 0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Budarkatti</td>
<td>0.62 0.00 1.20 0.00</td>
<td>1.82 0.00 0.00 1.63</td>
<td>2.22 0.24 2.00 0.00 0.00</td>
</tr>
<tr>
<td></td>
<td>Savadatti</td>
<td>Hireulligeri</td>
<td>0.84 0.00 0.00 0.00</td>
<td>0.00 0.00 1.21 0.22</td>
<td>0.48 0.00 0.80 0.80 0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inamhongal</td>
<td>0.00 0.00 0.21 0.00</td>
<td>1.64 0.42 0.00 1.24</td>
<td>1.82 0.00 1.28 0.00 0.00</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td>0.42 0.00 0.56 0.00</td>
<td>1.67 0.42 0.30 1.27</td>
<td>2.18 0.06 1.23 0.26 0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dharwad</td>
<td>Daddikamalapur</td>
<td>2.20 0.42 0.00 6.30</td>
<td>4.00 0.48 0.00 2.43</td>
<td>1.20 2.00 0.28 1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Madihal</td>
<td>1.82 0.20 0.88 0.00</td>
<td>3.24 1.80 0.00 1.10</td>
<td>4.40 3.00 1.00 0.84 0.00</td>
</tr>
<tr>
<td></td>
<td>Navalgund</td>
<td>Na-valgund</td>
<td>1.00 0.00 0.00 0.00</td>
<td>1.80 1.00 2.86 1.27</td>
<td>2.24 0.86 3.00 3.20 0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amargol</td>
<td>0.86 0.00 0.00 10.00</td>
<td>3.26 0.00 3.24 3.26</td>
<td>4.00 3.20 3.26 0.00 0.66</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td>1.47 0.16 0.22 4.08</td>
<td>3.08 0.82 1.53 2.02</td>
<td>2.71 2.07 2.37 1.08 0.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Byadgi</td>
<td>Shidenur</td>
<td>2.64 3.44 2.22 14.00</td>
<td>2.84 0.00 3.24 2.22</td>
<td>5.10 4.28 3.66 1.48 1.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Guddadmalapur</td>
<td>2.00 4.62 1.60 10.20</td>
<td>4.80 0.80 4.64 3.28</td>
<td>6.06 3.00 4.00 2.80 2.44</td>
</tr>
<tr>
<td></td>
<td>Rannebennur</td>
<td>Kakola</td>
<td>1.62 3.22 2.10 0.00</td>
<td>5.26 1.26 5.28 2.24</td>
<td>4.48 4.26 2.64 4.22 2.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hulihalli</td>
<td>2.43 5.21 0.00 8.00</td>
<td>3.62 0.00 3.85 2.20</td>
<td>2.22 6.20 2.88 4.00 3.42</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td>2.17 4.12 1.48 8.05</td>
<td>4.13 0.52 4.25 2.49</td>
<td>4.47 4.44 3.30 3.13 2.32</td>
</tr>
</tbody>
</table>


* Number of insects per plant, ** Number of insects on top 15 cm twig, # Number of webs per plant
4.1.2 Dharwad district

At pre-flowering stage

Dharwad district recorded the incidence of ash weevil, leaf webber, hairy caterpillar and aphids at pre-flowering stage of the crop during 2011-12 and 2012-13.

The high incidence of ash weevil (1.42 weevils/plant) and aphids (11.20 aphids/plant) was noticed in Daddikamalapur whereas, Amargol village recorded high population of leaf webber (3.87 webs/plant) and hairy caterpillar (0.87 larvae/plant) during 2011-12 (Table 6). During 2012-13, the incidence of ash weevil (2.20 weevils/plant) and leaf webber (0.42 webs/plant) was higher in Daddikamalapur, hairy caterpillar (0.88 larvae/plant) in Madihal and aphids (10.00 aphids/plant) in Amargol village (Table 7).

The mean population of ash weevil, leaf webber, hairy caterpillar and aphids in Dharwad district was 0.95, 1.83, 0.71 and 4.64 during 2011-12 and 1.47, 0.16, 0.22 and 4.08 during 2012-13, respectively.

At flowering stage

The incidence of bud weevil, hairy caterpillar, spotted pod borer and gram pod borer noticed in Dharwad district during 2011-12 and 2012-13.

The high population of bud weevil (4.64 weevils/plant) and spotted pod borer was (3.83 webs/plant) recorded in Amargol, hairy caterpillar (0.82 larvae/plant) in Daddikamalapur and gram pod borer (1.22 larvae/plant) in Madihal village during 2011-12 (Table 6). Amargol village recorded high incidence of spotted pod borer (3.24 webs/plant) and gram pod borer (3.26 larvae/plant) during 2012-13 whereas, bud weevil (4.00 weevils/plant) population was higher in Daddikamalapur and hairy caterpillar (1.80 larvae/plant) in Madihal village (Table 7).

The average population of bud weevil, hairy caterpillar, spotted pod borer and gram pod borer recorded in Dharwad district was 2.62, 0.47, 1.82 and 0.83 during 2011-12 and 3.08, 0.82, 1.53 and 2.02 during 2012-13, respectively.

At pod formation stage

The high incidence of bud weevil (3.63 weevils/plant), pod bugs (3.84 bugs/plant) and gram pod borer (3.63 larvae/plant) was recorded in Navalgund, blister beetle (3.44 beetles/plant) in Madihal and plume moth (0.80 larvae/plant) in Amargol during 2011-12 (Table 6). The higher population of pod bugs (3.20 bugs/plant) and gram pod borer (3.26 larvae/plant) was recorded in Amargol, bud weevil (4.40 weevils/plant) in Madihal, blister beetle (3.20 beetles/plant) in Navalgund and plume moth (1.00 larvae/plant) in Daddikamalapur village during 2012-13 (Table 7).

The mean population of bud weevil, pod bugs, gram pod borer, blister beetle and plume moth was 3.37, 1.94, 2.99, 0.86 and 0.42 during 2011-12 and 2.71, 2.07, 2.37, 1.08 and 0.42 during 2012-13, respectively in Dharwad district.

4.1.3 Haveri district

At pre-flowering stage

Among the four villages surveyed for the pest activity on the crop, the mean population of leaf webber (4.23 webs/plant) and hairy caterpillar (1.20 larvae/plant) was highest in Shidenur village whereas, ash weevil population (1.82 weevils/plant) was maximum in Kakola and aphids in Guddadmallapur (12.00 aphids/plant) during 2011-12 (Table 6). Shidenur village recorded the highest mean population of ash weevil (2.64 weevils/plant), hairy caterpillar (2.22 larvae/plant) and aphids (14.00 aphids/plant), while higher incidence of leaf webber (5.21 larvae/plant) was noticed in Hulihalli village of Haveri district during 2012-13 (Table 7).

The mean population of ash weevil, leaf webber (webs/plant), hairy caterpillar and aphids in Haveri district during 2011-12 was 1.52, 3.72, 1.01 and 5.54 and 2.17, 4.12, 1.48 and 8.05 during 2012-13, respectively.

At flowering stage

During the second survey at flowering stage of the crop, Haveri district recorded the incidence of bud weevil, hairy caterpillar, spotted pod borer and gram pod borer.
Among the four villages of Haveri district surveyed during 2011-12, the highest mean population of bud weevil (4.23 weevils/plant), spotted pod borer (5.22 webs/plant) and gram pod borer (1.66 larvae/plant) was recorded in Hulihalli whereas, the incidence of hairy caterpillar was higher in Guddadmallapur with mean population of 1.62 larvae per plant (Table 6). During 2012-13, Kakola village recorded higher incidence of bud weevil (5.26 weevils/plant), hairy caterpillar (1.26 larvae/plant) and spotted pod borer (5.28 webs/plant), while the mean population of gram pod borer (3.28 larvae/plant) was highest in Guddadmallapur (Table 7).

The mean population of bud weevil, hairy caterpillar, spotted pod borer and gram pod borer in Haveri district was 3.05, 0.77, 4.45 and 1.30 during 2011-12 and 4.13, 0.52, 4.25 and 2.49 during 2012-13, respectively.

At pod formation stage

Haveri district recorded the incidence of bud weevil, pod bugs, gram pod borer, blister beetle and plume moth during the third survey conducted at pod formation stage of the crop.

Out of four villages surveyed during 2011-12, the higher incidence of pod bugs, blister beetle and plume moth with mean population of 4.00, 6.86 and 1.20 was recorded in Hulihalli village of Haveri district, respectively, whereas the incidence of bud weevil (4.63 weevils/plant) was higher in Guddadmallapur and gram pod borer (3.22 larvae/plant) in Shidenur (Table 6). During 2012-13, the higher incidence of bud weevil (6.06 weevils/plant) and gram pod borer (4.00 larvae/plant) was recorded in Guddadmallapur and the incidence of pod bugs and plume moth was higher in Hulihalli with a mean population 6.20 bugs per plant and 3.42 larvae per plant whereas, Kakola village recorded higher incidence (4.22 beetles/plant) of blister beetle (Table 7).

The mean population of bud weevil, pod bugs, gram pod borer, blister beetle and plume moth in Haveri district was 4.17, 3.07, 2.14, 5.08 and 0.97 and 4.47, 4.44, 3.30, 3.13 and 2.32 during 2011-12 and 2012-13, respectively.

### 4.2 Seasonal abundance of major insect pests of pigeonpea in the northern transitional belt of Karnataka

#### 4.2.1 Seasonal incidence of insect pests of pigeonpea

The results of studies on seasonal incidence of major insect pests of pigeonpea carried out at MARS, Dharwad during 2011-12 and 2012-13 are presented in table 8 and 9.

The incidence of hairy caterpillars and leaf webber was noticed at the vegetative stage of the crop. The presence of spotted pod borer, bud weevil and blister beetle was noticed at flowering stage. The gram pod borer was appeared during flowering as well as pod formation stage. The occurrence of blister beetle and pod bugs was observed during pod formation stage.

##### 4.2.1.1 Hairy caterpillar

During the first year (2011-12), the incidence of hairy caterpillar started at 31st week (0.42 larvae/plant) and continued up to 35th week (0.80 larvae/plant), reached its peak at 34th week (2.22 larvae/plant) and thereafter it declined gradually (Table 8). During the second year (2012-13), the population ranged from 0.84 at 33rd week to 3.60 larvae per plant at 36th week and continued up to 37th week (1.12 larvae/plant) (Table 9).

##### 4.2.1.2 Leaf webber

In the first year, the leaf webber incidence started at 32nd week (1.20 webs/plant) and reached its peak at 35th week (5.20 webs/plant). Thereafter it declined and reached to minimum (0.48 webs/plant) at 37th week (Table 8). During second year, its incidence was started at 35th week (3.21 webs/plant) and continued up to 40th week (0.87 webs/plant) and reached its peak at 37th week (6.46 webs/plant) (Table 9).

##### 4.2.1.3 Spotted pod borer

During the first year, the incidence of spotted pod borer began at 44th week (4.82 webs/plant) and increased gradually reaching its peak at 45th week (5.44 webs/plant) then reached to a lowest of 3.62 webs per plant at 46th week (Table 8). In the second year, it appeared at 44th week (1.82 webs/plant) and continued up to 48th week (2.26 webs/plant) with a peak incidence at 47th week (5.24 webs/plant) (Table 9).
Table 8: Seasonal incidence of major insect pests of pigeonpea during 2011-12

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Insect pests</th>
<th>Meteorological Standard Weeks (MSW)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Hc</td>
<td>0.00 0.42 0.81 1.64 2.22 0.80 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td>Number of insects per plant except leaf webber and spotted pod borer</td>
</tr>
<tr>
<td>2</td>
<td>Lw</td>
<td>0.00 0.00 1.20 2.83 4.65 5.20 2.64 0.48 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Spb</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Gpb</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Bw</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Bb</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Pb</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pm</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td></td>
</tr>
</tbody>
</table>

**Unit**: Number of insects per plant except leaf webber and spotted pod borer

**Hc**: Hairy caterpillars

**Lw**: Leaf webber (Number of webs per plant)

**Spb**: Spotted pod borer (Number of webs per plant)

**Gpb**: Gram pod borer

**Bw**: Bud weevil

**Bb**: Blister beetle

**Pb**: Pod bug

**Pm**: Plume moth
Table 9: Seasonal incidence of major insect pests of pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Insect pests</th>
<th>Meteorological Standard Weeks (MSW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52</td>
</tr>
<tr>
<td>1</td>
<td>Hc</td>
<td>0.00  0.00  0.00  0.84  1.85  2.82  3.60  1.12  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00</td>
</tr>
<tr>
<td>2</td>
<td>Lw</td>
<td>0.00  0.00  0.00  0.00  3.21  5.63  6.46  2.82  1.18  0.87  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00</td>
</tr>
<tr>
<td>3</td>
<td>Spb</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00</td>
</tr>
<tr>
<td>4</td>
<td>Gpb</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  2.21  2.80  3.20  4.46  7.48  9.81</td>
</tr>
<tr>
<td>5</td>
<td>Bw</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  2.28  4.60  6.43  8.22  5.84</td>
</tr>
<tr>
<td>6</td>
<td>Bb</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  1.62  1.25  0.00  0.00</td>
</tr>
<tr>
<td>7</td>
<td>Pb</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.84  2.66  3.25  1.86  0.82</td>
</tr>
<tr>
<td>8</td>
<td>Pm</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  1.22  1.68  2.86</td>
</tr>
</tbody>
</table>

Unit: Number of insects per plant except leaf webber and spotted pod borer

Hc: Hairy caterpillars  
Lw: Leaf webber (Number of webs per plant)  
Spb: Spotted pod borer (Number of webs per plant)  
Gpb: Gram pod borer  
Bw: Bud weevil  
Bb: Blister beetle  
Pb: Pod bug  
Pm: Plume moth
4.2.1.4 Gram pod borer

During the first year, the population of gram pod borer was 1.10 larvae per plant at 43\textsuperscript{rd} week and increased to 8.23 larvae per plant at 48\textsuperscript{th} week. Thereafter it declined and reached to a minimum of 3.28 larvae per plant at 51\textsuperscript{st} week (Table 8). In the second year, similar trend was also noticed with population ranging from 2.21 larvae per plant at 43\textsuperscript{rd} week to 9.81 larvae per plant at 48\textsuperscript{th} week, thereafter it declined to 5.24 larvae per plant at 51\textsuperscript{st} week (Table 9).

4.2.1.5 Bud weevil

The bud weevil population during the first year was 3.24 weevils per plant at 45\textsuperscript{th} week and gradually increased to 7.86 weevils per plant (47\textsuperscript{th} week) and then declined to 1.26 weevils per plant at 50\textsuperscript{th} week (Table 8). During the second year, it varied from 2.28 weevils per plant (44\textsuperscript{th} week) to 2.82 weevils per plant (50\textsuperscript{th} week) with a peak of 8.22 weevils per plant at 47\textsuperscript{th} week (Table 9).

4.2.1.6 Blister beetle

The incidence of blister beetle in the first year was noticed at 45\textsuperscript{th} week (1.25 beetles/plant) and 46\textsuperscript{th} weeks (0.86 beetles/plant) (Table 8) whereas, during the second year it appeared from 43\textsuperscript{rd} week (0.84 beetles/plant) to 45\textsuperscript{th} week (1.25 beetles/plant) with a maximum population of 1.62 beetles per plant at 44\textsuperscript{th} week (Table 9).

4.2.1.7 Pod bugs

The incidence of pod bugs during the first year started at 43\textsuperscript{rd} week (1.24 bugs/plant) and continued up to 47\textsuperscript{th} week (0.85 bugs/plant) with a peak population of 1.83 bugs per plant at 44\textsuperscript{th} week (Table 8). During second year, it appeared at 42\textsuperscript{nd} week (0.84 bugs/plant) and gradually increased to 3.25 bugs per plant at 44\textsuperscript{th} week. Thereafter it declined and reached to 0.64 bugs per plant at 47\textsuperscript{th} week (Table 9).

4.2.1.8 Plume moth

During the first year, the incidence of plume moth was noticed at 47\textsuperscript{th} week (1.85 larvae/plant) and continued up to 50\textsuperscript{th} week (1.24 larvae/plant) (Table 8) whereas, in the second year, it appeared at 46\textsuperscript{th} week (1.22 larvae/plant) and reached its peak at 48\textsuperscript{th} week (2.86 larvae/plant). Further it was reduced to a lowest population level of 1.14 larvae per plant at 50\textsuperscript{th} week (Table 9).

4.2.2 Influence of weather parameters on insect pests of pigeonpea

The incidence of insect pests was correlated with various weather factors (maximum temperature, minimum temperature, relative humidity and rainfall) to assess the influence of weather factors on pest incidence and presented in table 10 and 11.

4.2.2.1 Hairy caterpillars

The incidence of hairy caterpillars during first year was significantly and negatively correlated with mean maximum temperature ($r= -0.450$) and positively correlated with mean relative humidity ($r=0.424$). However, the correlation coefficient of population of hairy caterpillars with mean minimum temperature and mean rainfall was not significant. The incidence of hairy caterpillars was influenced to an extent of 26.00 per cent by all weather parameters (Table 10).

During the second year, the incidence of hairy caterpillars was significantly and positively correlated with mean minimum temperature ($r=0.437$) whereas, the correlation coefficient was non-significant with mean maximum temperature, mean relative humidity and mean rainfall. All the weather factors together influenced the pest incidence to an extent of 30.10 per cent (Table 11).

4.2.2.2 Leaf webber

The incidence of leaf webber was significantly and positively correlated with mean minimum temperature ($r=0.416$) and mean relative humidity ($r=0.521$) and negatively with mean maximum temperature ($r=0.641$) during first year. There was 42 per cent influence of weather parameters on incidence of leaf webber (Table 10).

During the second year, the correlation coefficient was significant and positive with mean minimum temperature ($r=0.438$). The correlation coefficient with mean maximum temperature, mean relative humidity, mean rainfall was not significant. All the weather factors together influenced the pest to the tune of 24.90 per cent (Table 11).
Table 10: Relationship of weather parameters with insect pests of pigeonpea during 2011-12

<table>
<thead>
<tr>
<th>Insect pests</th>
<th>Correlation coefficient (r)</th>
<th>R²</th>
<th>Regression equation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weather parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean max. Temperature (X₁) (°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean min. Temperature (X₂) (°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean relative humidity (X₃) (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Rainfall (X₄) (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hairy caterpillars</td>
<td>-0.450*</td>
<td>0.381</td>
<td>0.424*</td>
</tr>
<tr>
<td>Leaf webber</td>
<td>-0.641**</td>
<td>0.416*</td>
<td>0.521*</td>
</tr>
<tr>
<td>Spotted pod borer</td>
<td>0.379</td>
<td>-0.229</td>
<td>-0.419*</td>
</tr>
<tr>
<td>Gram pod borer</td>
<td>0.428*</td>
<td>-0.601**</td>
<td>-0.382</td>
</tr>
<tr>
<td>Bud weevil</td>
<td>0.381</td>
<td>-0.490*</td>
<td>-0.503*</td>
</tr>
<tr>
<td>Blister beetle</td>
<td>0.333</td>
<td>-0.284</td>
<td>-0.503*</td>
</tr>
<tr>
<td>Pod bugs</td>
<td>0.401</td>
<td>-0.221</td>
<td>-0.383</td>
</tr>
<tr>
<td>Plume moth</td>
<td>0.282</td>
<td>-0.444*</td>
<td>-0.237</td>
</tr>
</tbody>
</table>

* Significant at 0.05 level
** Significant at 0.01 level
### Table 11: Relationship of weather parameters with insect pests of pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Insect pests</th>
<th>Correlation coefficient (r)</th>
<th>( R^2 )</th>
<th>Regression equation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( X_1 ) (^{\circ}) C</td>
<td>( X_2 ) (^{\circ}) C</td>
<td>( X_3 )%</td>
</tr>
<tr>
<td>Hairy caterpillars</td>
<td>-0.226</td>
<td>0.437*</td>
<td>0.328</td>
</tr>
<tr>
<td>Leaf webber</td>
<td>-0.101</td>
<td>0.438*</td>
<td>0.327</td>
</tr>
<tr>
<td>Spotted pod borer</td>
<td>-0.044</td>
<td>-0.466*</td>
<td>-0.416*</td>
</tr>
<tr>
<td>Gram pod borer</td>
<td>0.125</td>
<td>-0.759**</td>
<td>-0.647**</td>
</tr>
<tr>
<td>Bud weevil</td>
<td>0.023</td>
<td>-0.596**</td>
<td>-0.537**</td>
</tr>
<tr>
<td>Blister beetle</td>
<td>0.004</td>
<td>0.057</td>
<td>-0.008</td>
</tr>
<tr>
<td>Pod bugs</td>
<td>-0.031</td>
<td>-0.142</td>
<td>-0.215</td>
</tr>
<tr>
<td>Plume moth</td>
<td>-0.010</td>
<td>-0.615**</td>
<td>-0.547**</td>
</tr>
</tbody>
</table>

* Significant at 0.05 level
** Significant at 0.01 level
4.2.2.3 Spotted pod borer

Mean relative humidity showed a significant negative correlation with incidence of spotted pod borer ($r=-0.419$) during first year (Table 10). Further, it was non-significant with mean maximum temperature, mean minimum temperature and mean rainfall. However, the weather factors collectively influenced the pest incidence to an extent of 21.80 per cent.

During the second year, mean minimum temperature and mean relative humidity had significant negative correlation ($r=-0.446$ and $r=-0.416$) with pest incidence whereas mean maximum temperature and mean rainfall was non-significant and negative with the pest incidence. The overall impact of weather factors on pest incidence was 24.60 per cent (Table 11).

4.2.2.4 Gram pod borer

The incidence of gram pod borer showed significantly positive correlation with mean maximum temperature ($r=0.428$) and significantly negative correlation with mean minimum temperature ($r=-0.601$) and mean rainfall ($r=-0.420$) during the first year (Table 10). Further the correlation coefficient was non-significant between mean relative humidity and gram pod borer population.

During the second year, significant negative correlation was noticed between gram pod borer incidence and mean minimum temperature ($r=-0.759$), mean relative humidity ($r=-0.647$), mean rainfall ($r=-0.560$) whereas, mean maximum temperature had non-significant positive relationship with pest incidence (Table 11).

The combined and overall impact of all the weather parameters on gram pod borer population was 41.30 and 63.50 per cent during first and second year.

4.2.2.5 Bud weevil

The incidence of bud weevil, during first year showed a significant negative correlation with mean minimum temperature ($r=-0.490$) and mean relative humidity ($r=-0.503$), whereas the incidence was non-significant with mean maximum temperature and mean rainfall (Table 10).

During the second year, the incidence was significantly and negatively correlated with mean minimum temperature ($r=-0.596$), mean relative humidity ($r=-0.537$) and mean rainfall ($r=-0.462$). However, non-significant correlation was observed between incidence of bud weevil and mean maximum temperature (Table 11).

All the weather parameters influenced the abundance of bud weevil to an extent of 31.30 and 39.90 per cent during first and second year.

4.2.2.6 Blister beetle

Mean relative humidity had a significant negative correlation ($r=-0.503$) with population of blister beetle during the first year whereas, mean maximum temperature, mean minimum temperature and mean rainfall showed non-significant correlation with pest incidence (Table 10).

During the second year, correlation between incidence of blister beetle and weather parameters (mean maximum temperature, mean minimum temperature, mean relative humidity and mean rainfall) was found to be non-significant (Table 11).

The combined influence of all weather parameters on blister beetle population was 26.40 and 1.90 per cent during first and second years of study.

4.2.2.7 Pod bugs

The incidence of pod bugs was non-significantly correlated with various weather parameters (mean maximum temperature, mean minimum temperature, mean relative humidity and mean rainfall) during both the years of study.

However, overall impact of weather parameters on pod bugs abundance was 23.50 and 7.30 per cent during first and second year study period (Table 10 and 11).

4.2.2.8 Plume moth

During the first year, mean minimum temperature showed a significantly negative correlation ($r=-0.444$) with population of plume moth and non-significant correlation with remaining weather parameters (mean maximum temperature, mean relative humidity and mean rainfall) (Table 10).
During the second year, population of plume moth correlated significantly and negatively with mean minimum temperature ($r=-0.615$), mean relative humidity ($r=-0.547$) and mean rainfall ($r=-0.454$). However, it was non-significant with mean maximum temperature (Table 11).

The weather factors together influenced the plume moth incidence to the tune of 22.20 and 42.00 per cent during first and second years of study period.

4.2.3 Insect pest scenario of pigeonpea in transitional region of Karnataka

4.2.3.1 Insect pests

A total of 31 insect pests were recorded from pigeonpea ecosystem during the course of investigation, majority belonged to lepidoptera followed by hemiptera, coleoptera, diptera, hymenoptera, thysanoptera and orthoptera (Table 12). The appearance of pest commenced right from the emergence of crop and continued till the harvest. These insect pests infesting the different stages of the crop growth are depicted in plates 3, 4 and 5.

4.2.3.2 Natural enemies

The natural enemies (parasitoids, arthropod predators and predatory birds) recorded in pigeonpea ecosystem during the course of investigation are presented in Table 13 (Plates 6, 7 and 8).

4.2.4 Effect of dates of sowing on the incidence of insect pests of pigeonpea

4.2.4.1 Gall weevil

The observations on effect of dates of sowing on the incidence of gall weevil, *Alcidodes collaris* Pascoe recorded at 15, 25, 35 and 45 days after crop emergence (DACE) is presented in table 14 and 15.

At 15 DACE

In the first year, the crop sown during first week of June recorded significantly lower incidence of gall weevil (10.00%) and was on par with the crop sown during third week of June (11.45%). Thereafter, the incidence increased in subsequent sowings and significantly higher incidence (74.29%) was noticed in crop sown during first week of August (Table 14). Similar trend was observed during second year also and the lowest per cent incidence was noticed on crop sown during first week of June (12.80%) which was on par with the crop sown during third week of June (14.88%) and first week of July (16.14%). Significantly highest gall weevil incidence of 75.96 per cent was recorded on the crop sown during August first week (Table 15).

At 25 DACE

During the first year, the incidence of gall weevil was ranged from 12.85 per cent on crop sown at June first week to 75.71 per cent on crop sown at August first week (Table 14). During the second year, significantly lowest incidence of 14.85 per cent was recorded on crop sown at first week of June which was on par with crop sown at third week of June (16.20%) and first week of July (17.44%). Significantly higher gall weevil incidence of 77.14 per cent was recorded on the crop sown at August first week (Table 15).

At 35 DACE

The lowest per cent galled plants (14.28%) were noticed on crop sown during June first week. However, it was on par with next date of sowing done at third week of June (17.84%) and significantly higher per cent galled plants of 88.32 per cent were observed in late sown crop (August first week) during the first year (Table 14). The pest incidence ranged between 17.14 (June first sown crop) to 90.00 per cent (August first sown crop) during the second year. However incidence on crop sown during the first week of June was statistically on par with crop sown at third week of June (17.21%) and first week of July (18.43%) (Table 15).

At 45 DACE

Least per cent galled plants (15.71%) were recorded on the crop sown during first week of June, which was at par with sowings done during third week of June (20.00%) and first week of July
Table 12: Insect pest scenario of pigeonpea in northern transitional region of Karnataka

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lepidoptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Leaf webber</td>
<td>Grapholita (=Eucosma=Cydia) critica Meyr.</td>
<td>Tortricidae</td>
</tr>
<tr>
<td>2</td>
<td>Semilooper</td>
<td>Pericallia ricini Fab.</td>
<td>Arctiidae</td>
</tr>
<tr>
<td>3</td>
<td>Red hairy caterpillar</td>
<td>Amsacta spp.</td>
<td>Arctiidae</td>
</tr>
<tr>
<td>4</td>
<td>Spiny pod borer</td>
<td>Etiella zinckenella Treitschke</td>
<td>Pyralidae</td>
</tr>
<tr>
<td>5</td>
<td>Spotted pod borer</td>
<td>Maruca vitrata (Geyer)</td>
<td>Pyralidae</td>
</tr>
<tr>
<td>6</td>
<td>Gram pod borer</td>
<td>Helicoverpa armigera (Hubner)</td>
<td>Noctuidae</td>
</tr>
<tr>
<td>7</td>
<td>Tussock caterpillar</td>
<td>Euproctis subnotata Walker</td>
<td>Lymnantridae</td>
</tr>
<tr>
<td>8</td>
<td>Groundnut leaf miner</td>
<td>Aproaerema modicella Devanter</td>
<td>Gelicidiae</td>
</tr>
<tr>
<td>9</td>
<td>Blue butterfly</td>
<td>Lampides boeticus (L.)</td>
<td>Lycaenidae</td>
</tr>
<tr>
<td>10</td>
<td>Plume moth</td>
<td>Exelastis atomosa (May.)</td>
<td>Pterophoridae</td>
</tr>
<tr>
<td>11</td>
<td>Bagworm</td>
<td>Unidentified</td>
<td>Cossidae,</td>
</tr>
<tr>
<td>12</td>
<td>Bell moth</td>
<td>Unidentified</td>
<td>Tortricidae</td>
</tr>
<tr>
<td>13</td>
<td>Tussock caterpillar</td>
<td>Unidentified</td>
<td>Lymnantridae</td>
</tr>
<tr>
<td></td>
<td>Hemiptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Pod sucking bug</td>
<td>Anoplocnemis phasiana (Fabricius)</td>
<td>Coreidae</td>
</tr>
<tr>
<td>15</td>
<td>Pod sucking bug</td>
<td>Clavigralla gibbosa Spinola</td>
<td>Coreidae</td>
</tr>
<tr>
<td>16</td>
<td>Pod sucking bug</td>
<td>Riptortus pedestris (F.)</td>
<td>Coreidae</td>
</tr>
<tr>
<td>17</td>
<td>Pod sucking bug</td>
<td>Nezara viridula (L.)</td>
<td>Pentatomidae</td>
</tr>
<tr>
<td>18</td>
<td>Green striped leaf hopper</td>
<td>Eurybrachys tomentosus. F.</td>
<td>Eurybrachidae.</td>
</tr>
<tr>
<td>19</td>
<td>Cow bug</td>
<td>Otinotus oneratus W.</td>
<td>Membracidae</td>
</tr>
<tr>
<td>20</td>
<td>Aphids</td>
<td>Aphis craccivora Koch</td>
<td>Aphididae</td>
</tr>
<tr>
<td>21</td>
<td>Leaf hopper</td>
<td>Empoasca kerri Pruthi</td>
<td>Cicadellidae</td>
</tr>
<tr>
<td></td>
<td>Coleoptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Gall weevil</td>
<td>Alcidodes collaris Pascoe</td>
<td>Curculionidae</td>
</tr>
<tr>
<td>23</td>
<td>Bruchids</td>
<td>Callosobruchus spp</td>
<td>Bruchidae</td>
</tr>
<tr>
<td>24</td>
<td>Jewel beetle (stem borer)</td>
<td>Sphenoptera indica Laporte and Gory</td>
<td>Buprestidae</td>
</tr>
<tr>
<td>25</td>
<td>Ash weevil</td>
<td>Myllocerus discolor F.</td>
<td>Curculionidae</td>
</tr>
<tr>
<td>26</td>
<td>Bud weevil</td>
<td>Cethhorhynchus asperulus (Faust)</td>
<td>Curculionidae</td>
</tr>
<tr>
<td>27</td>
<td>Blister beetle</td>
<td>Mylabris pustulata (Thunberg)</td>
<td>Meloiidae</td>
</tr>
<tr>
<td></td>
<td>Diptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Pod fly</td>
<td>Melanagromyza obtusa (Malloch)</td>
<td>Agromyzidae</td>
</tr>
<tr>
<td></td>
<td>Thysanoptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Thrips</td>
<td>Megalurothrips usitatus (Bagnall)</td>
<td>Thripidae</td>
</tr>
<tr>
<td></td>
<td>Hymenoptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Leaf cutter bee</td>
<td>Megachile spp.</td>
<td>Megachilidae</td>
</tr>
<tr>
<td></td>
<td>Orthoptera:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Deccan wingless grasshopper</td>
<td>Colemania sphenarioides Bol.</td>
<td>Acrididae</td>
</tr>
</tbody>
</table>
Plate 3: Insect pests of pigeonpea occurring during the vegetative stage of the crop

Tussock caterpillar, *Euproctis subnotata* Walker

Leaf webber, *Grapholitha critica* Meyr.

Semilooper, *Pericalia ricini* Fab.

Red headed hairy caterpillars, *Amsacta* spp.

Green striped leaf hopper, *Eurybrachys tomentosus* F.

Cow bug, *Otinotus oneratus* W.
Plate 3 Contd.....

Aphids, *Aphis craccivora* Koch

Leaf hopper, *Empoasca kerri* Pruthi

Gall weevil, *Alciododes collaris* Pascoe

Ash weevil, *Myllocerus discolor* F.

Leaf cutter bee, *Megachile* spp.

Deccan wingless grasshopper, *Colemania sphenarioides* Bol.
Plate 4: Insect pests of pigeonpea occurring during the flowering stage of the crop
Plate 5: Insect pests of pigeonpea occurring during the pod formation stage of the crop
Plate 5 Contd.....

Pod sucking bug, *Anoplocnemis phasiana* (Fabricius)

Pod sucking bug, *Clavigrella gibbosa* Spinola

Pod sucking bug, *Reptortus pedesris* (F.)

Pod sucking bug, *Nezara viridula* (L.)
## Table 13: Natural enemies of insect pests of pigeonpea

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Scientific name</th>
<th>Family</th>
<th>Order</th>
<th>Host</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Campoletis chlorideae</em> Uchida</td>
<td>Ichneumonidae</td>
<td>Hymenoptera</td>
<td><em>Helicoverpa armigera</em> (Hubner)</td>
</tr>
<tr>
<td>2</td>
<td><em>Apanteles taragamae</em> Viereck</td>
<td>Braconidae</td>
<td>Hymenoptera</td>
<td><em>Maruca vitrata</em> (Geyer)</td>
</tr>
<tr>
<td>3</td>
<td><em>Apanteles</em> sp.</td>
<td>Braconidae</td>
<td>Hymenoptera</td>
<td><em>H. armigera</em></td>
</tr>
<tr>
<td>4</td>
<td><em>Glyptapanteles</em> sp.</td>
<td>Braconidae</td>
<td>Hymenoptera</td>
<td>Arctiidae</td>
</tr>
<tr>
<td>5</td>
<td><em>Telenomus</em> sp.</td>
<td>Scelionidae</td>
<td>Hymenoptera</td>
<td><em>H. armigera</em></td>
</tr>
<tr>
<td>6</td>
<td>Unidentified</td>
<td>Tachinidae</td>
<td>Diptera</td>
<td><em>H. armigera</em></td>
</tr>
</tbody>
</table>

### Parasitoids

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Family</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lady bird beetle</td>
<td><em>Cheilomenes sexmaculata</em> (Fabricius)</td>
<td>Coccinellidae</td>
<td>Coleoptera</td>
</tr>
<tr>
<td>2</td>
<td>Green lacewing</td>
<td><em>Chrysoperla carnea</em> (Stephens)</td>
<td>Chrysopidae</td>
<td>Neuroptera</td>
</tr>
<tr>
<td>3</td>
<td>Reduvid bug</td>
<td>Unidentified</td>
<td>Reduvidae</td>
<td>Hemiptera</td>
</tr>
<tr>
<td>4</td>
<td>Dragonfly</td>
<td>Unidentified</td>
<td>Unidentified</td>
<td>Odonata</td>
</tr>
<tr>
<td>5</td>
<td>Spider</td>
<td>Unidentified</td>
<td>Unidentified</td>
<td>Araneae</td>
</tr>
</tbody>
</table>

## Arthropod predators

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Common name</th>
<th>Scientific name</th>
<th>Family</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black drongo</td>
<td><em>Dicrurus macrocercus</em> (Vieillot)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Green bee eater</td>
<td><em>Merops orientalis</em> (Latham)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mynah</td>
<td><em>Acridotheres tristis</em> (Linnaeus)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Crow</td>
<td><em>Corvus splendens</em> (Vieillot)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Plate 6: Parasitoids in pigeonpea ecosystem

*Campoletis chlorideae* Uchida

*Apanteles taragamae* Viereck

*Apanteles* sp.

*Glyptapanteles* sp.

*Telenomus* sp.

*Tachinid fly*
Plate 7: Arthropod predators in pigeonpea ecosystem

Lady bird beetle, *Cheilomenes sexmaculata* (Fabricius)

Reduvid bug

Dragonfly

Green lacewing, *Chrysoperla carnea* (Stephens)

Spiders
Plate 8: Predatory birds in pigeonpea ecosystem

Black drongo,
*Dicrurus macrocercus* (Vieillot)

Green bee eater,
*Merops orientalis* (Latham)
Table 14: Effect of dates of sowing on the incidence of gall weevil (*Alcidodes collaris* Pascoe) during 2011-12

<table>
<thead>
<tr>
<th>Dates of sowing</th>
<th>15 DACE</th>
<th>25 DACE</th>
<th>35 DACE</th>
<th>45 DACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>June first week</td>
<td>10.00</td>
<td>12.85</td>
<td>14.28</td>
<td>15.71</td>
</tr>
<tr>
<td></td>
<td>(18.39)</td>
<td>(20.93)</td>
<td>(22.13)</td>
<td>(23.23)</td>
</tr>
<tr>
<td>June third week</td>
<td>11.45</td>
<td>17.14</td>
<td>17.84</td>
<td>20.00</td>
</tr>
<tr>
<td></td>
<td>(19.76)</td>
<td>(24.43)</td>
<td>(24.97)</td>
<td>(26.55)</td>
</tr>
<tr>
<td>July first week</td>
<td>18.57</td>
<td>20.57</td>
<td>21.57</td>
<td>23.29</td>
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<tr>
<td></td>
<td>(25.49)</td>
<td>(26.92)</td>
<td>(27.65)</td>
<td>(28.83)</td>
</tr>
<tr>
<td>July third week</td>
<td>50.00</td>
<td>56.89</td>
<td>60.00</td>
<td>78.57</td>
</tr>
<tr>
<td></td>
<td>(45.00)</td>
<td>(49.03)</td>
<td>(50.79)</td>
<td>(62.50)</td>
</tr>
<tr>
<td>August first week</td>
<td>74.29</td>
<td>75.71</td>
<td>88.32</td>
<td>88.57</td>
</tr>
<tr>
<td></td>
<td>(59.79)</td>
<td>(60.54)</td>
<td>(70.49)</td>
<td>(70.96)</td>
</tr>
<tr>
<td>SEm (±)</td>
<td>1.69</td>
<td>1.71</td>
<td>1.54</td>
<td>1.82</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>5.22</td>
<td>5.25</td>
<td>4.74</td>
<td>5.61</td>
</tr>
</tbody>
</table>

DACE: Days after crop emergence  
* Mean of four replications  
Values in parentheses are arc sine transformations  
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

Table 15: Effect of dates of sowing on the incidence of gall weevil (*Alcidodes collaris* Pascoe) during 2012-13

<table>
<thead>
<tr>
<th>Dates of Sowing</th>
<th>15 DACE</th>
<th>25 DACE</th>
<th>35 DACE</th>
<th>45 DACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>June first week</td>
<td>12.80</td>
<td>14.85</td>
<td>17.14</td>
<td>18.43</td>
</tr>
<tr>
<td></td>
<td>(20.89)</td>
<td>(22.63)</td>
<td>(24.41)</td>
<td>(25.39)</td>
</tr>
<tr>
<td>June third week</td>
<td>14.88</td>
<td>16.20</td>
<td>17.21</td>
<td>21.23</td>
</tr>
<tr>
<td></td>
<td>(20.67)</td>
<td>(23.68)</td>
<td>(24.41)</td>
<td>(27.39)</td>
</tr>
<tr>
<td>July first week</td>
<td>16.14</td>
<td>17.44</td>
<td>18.43</td>
<td>21.86</td>
</tr>
<tr>
<td></td>
<td>(23.67)</td>
<td>(24.59)</td>
<td>(25.36)</td>
<td>(27.83)</td>
</tr>
<tr>
<td>July third week</td>
<td>51.43</td>
<td>55.27</td>
<td>62.86</td>
<td>80.00</td>
</tr>
<tr>
<td></td>
<td>(45.83)</td>
<td>(48.05)</td>
<td>(52.56)</td>
<td>(63.81)</td>
</tr>
<tr>
<td>August first week</td>
<td>75.96</td>
<td>77.14</td>
<td>90.00</td>
<td>90.00</td>
</tr>
<tr>
<td></td>
<td>(60.69)</td>
<td>(61.59)</td>
<td>(71.73)</td>
<td>(71.77)</td>
</tr>
<tr>
<td>SEm (±)</td>
<td>0.97</td>
<td>1.71</td>
<td>1.60</td>
<td>1.94</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>2.99</td>
<td>5.27</td>
<td>4.93</td>
<td>5.98</td>
</tr>
</tbody>
</table>

DACE: Days after crop emergence  
* Mean of four replications  
Values in parentheses are arc sine transformations  
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
whereas, highest per cent galled plants (88.57%) were noticed on the crop sown during first week of August in the first year (Table 14). During the second year, crop sown at first week of June recorded significantly lower per cent galled plants of 18.43 which was on par with the incidence on crop sown during third week of June (21.23%) and first week of July (21.86%). Significantly higher incidence of gall weevil was noticed on August first week sown pigeonpea with 90.00 per cent galled plants (Table 15).

4.2.4.2 Hairy caterpillars

The least population of hairy caterpillars (1.88 larvae/plant) recorded on crop sown at first week of June, which was statistically on par with sowings done during third week of June (1.90 larvae/plant), first week of July (2.18 larvae/plant) and third week of July (2.24 larvae/plant) whereas, highest population of 2.87 larvae per plant was noticed on crop sown at first week of August during the first year (Table 16). Similar trend was observed during second year and population ranged from 2.35 (June first week sown crop) to 3.86 larvae per plant (August first week sown crop). However, population density on crop sown during first week of June was statistically on par with sowings done during third week of June (2.90 larvae/plant) and first week of July (3.00 larvae/plant) (Table 17).

4.2.4.3 Leaf webber

During the first year, least incidence of leaf webber (2.80 webs/plant) recorded on June third week sown crop, which was on par with sowings done during first week of June (3.00 webs/plant) and first week of July (2.88 webs/plant) and highest incidence (6.50 webs/plant) on August first week sown crop (Table 16). Similar trend was observed during second year and the incidence ranged from 3.00 webs per plant on a crop sown at June first week to 5.66 webs per plant on July third week sown crop (Table 17).

4.2.4.4 Spotted pod borer

The incidence of spotted pod borer was lowest (4.60 webs/plant) on June first week sown crop and was found on par with crop sown during third week of June (4.84 webs/plant) and first week of July (4.80 webs/plant). Highest incidence of 8.20 webs per plant was recorded on late sown crop (August first week) during the first year (Table 16). Similar trend was observed during second year and incidence varied from 3.80 webs per plant (June first week sowing) to 7.24 webs per plant (August first week sowing) (Table 17).

4.2.4.5 Gram pod borer

The crop sown during first week of June recorded lowest population of 3.78 larvae per plant which was being on par with sowings done during third week of June (4.00 larvae/plant) and first week of July (4.24 larvae/plant) in the first year whereas, sowings done during third week of July resulted in significantly higher population of 7.44 larvae per plant (Table 16). Similar trend was observed during the second year also with least population of 4.00 larvae per plant recorded on June first week sown crop and highest on August first week sown crop (7.64 larvae/plant) (Table 17).

4.2.4.6 Bud weevil

The bud weevil incidence during the first year was least (4.50 weevils/plant) on the crop sown at first week of June, which was on par with sowings done during third week of June (4.53 weevils/plant) and first week of July (5.46 weevils/plant) and significantly higher incidence (8.20 weevils/plant) was noticed on crop sown at third week of July (Table 16). The similar trend was noticed during second year with lower incidence (4.70 weevils/plant) on the crop sown at first week of June and highest (7.30 weevils/plant) on July third week sown crop (Table 17).

4.2.4.7 Blister beetle

The blister beetle population was least on crop sown during first week of August (0.76 beetles/plant), which was statistically on par with sowings done during third week of July (0.88 beetles/plant) and first week of June (1.08 beetles/plant) whereas, significantly highest population of blister beetle was observed on the crop sown at third week of June (1.47 beetles/plant) in the first year (Table 16). During second year the least incidence of blister beetle was noticed on the crop sown during third week of July (0.84 beetles/plant) and highest (1.50 beetles/plant) on the crop sown at third week of June (Table 17).
**Table 16: Effect of dates of sowing on the incidence of major insect pests of pigeonpea during 2011-12**

<table>
<thead>
<tr>
<th>Dates of sowing</th>
<th>Hairy caterpillars (No/plant)</th>
<th>Leaf webber (Webs/plant)</th>
<th>Spotted pod borer (webs/plant)</th>
<th>Gram pod borer (webs/plant)</th>
<th>Bud weevil (Webs/plant)</th>
<th>Blister beetle (Webs/plant)</th>
<th>Pod bug (Webs/plant)</th>
<th>Plume moth (Webs/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June first week</td>
<td>1.88 (1.54) ab</td>
<td>3.00 (1.87) a</td>
<td>4.60 (2.25) a</td>
<td>3.78 (2.06) a</td>
<td>4.50 (2.23) a</td>
<td>1.08 (1.22) ab</td>
<td>1.53 (1.42) ba</td>
<td>1.13 (1.27) a</td>
</tr>
<tr>
<td>June third week</td>
<td>1.90 (1.55) ab</td>
<td>2.80 (1.82) a</td>
<td>4.84 (2.30) a</td>
<td>4.00 (2.12) a</td>
<td>4.53 (2.24) a</td>
<td>1.47 (1.40) c</td>
<td>1.11 (1.26) a</td>
<td>1.44 (1.38) ab</td>
</tr>
<tr>
<td>July first week</td>
<td>2.18 (1.63) ab</td>
<td>2.88 (1.83) a</td>
<td>4.80 (2.30) a</td>
<td>4.24 (2.17) a</td>
<td>5.46 (2.44) ab</td>
<td>1.20 (1.30) bc</td>
<td>1.64 (1.46) bc</td>
<td>1.80 (1.51) bc</td>
</tr>
<tr>
<td>July third week</td>
<td>2.24 (1.65) ab</td>
<td>5.80 (2.51) b</td>
<td>6.60 (2.66) b</td>
<td>7.44 (2.81) b</td>
<td>8.20 (2.95) c</td>
<td>0.88 (1.17) a</td>
<td>2.10 (1.61) d</td>
<td>2.00 (1.58) c</td>
</tr>
<tr>
<td>August first week</td>
<td>2.87 (1.83) b</td>
<td>6.50 (2.64) b</td>
<td>8.20 (2.94) b</td>
<td>6.10 (2.56) b</td>
<td>6.63 (2.66) b</td>
<td>0.76 (1.12) a</td>
<td>2.00 (1.58) bd</td>
<td>2.18 (1.63) c</td>
</tr>
<tr>
<td>SEm (±)</td>
<td>0.04</td>
<td>0.08</td>
<td>0.09</td>
<td>0.08</td>
<td>0.08</td>
<td>0.04</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>0.14</td>
<td>0.25</td>
<td>0.28</td>
<td>0.25</td>
<td>0.26</td>
<td>0.11</td>
<td>0.13</td>
<td>0.18</td>
</tr>
</tbody>
</table>

* Mean of four replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
Table 17: Effect of dates of sowing on the incidence of major insect pests of pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Dates of sowing</th>
<th>Hairy caterpillars</th>
<th>Leaf webber (webs/plant)</th>
<th>Spotted pod borer (webs/plant)</th>
<th>Gram pod borer</th>
<th>Bud weevil</th>
<th>Blister beetle</th>
<th>Pod bug</th>
<th>Plume moth</th>
</tr>
</thead>
<tbody>
<tr>
<td>June first week</td>
<td>2.35 (1.68)</td>
<td>3.00 (1.87)</td>
<td>3.80 (2.07)</td>
<td>4.00 (2.12)</td>
<td>4.70 (2.28)</td>
<td>1.16 (1.28)</td>
<td>1.88</td>
<td>0.92</td>
</tr>
<tr>
<td>June third week</td>
<td>2.90 (1.84)</td>
<td>3.30 (1.94)</td>
<td>4.20 (2.16)</td>
<td>4.06 (2.13)</td>
<td>4.74 (2.29)</td>
<td>1.50 (1.41)</td>
<td>1.67</td>
<td>1.10</td>
</tr>
<tr>
<td>July first week</td>
<td>3.00 (1.87)</td>
<td>3.82 (2.07)</td>
<td>4.80 (2.30)</td>
<td>4.84 (2.30)</td>
<td>5.00 (2.34)</td>
<td>1.40 (1.37)</td>
<td>2.00</td>
<td>1.20</td>
</tr>
<tr>
<td>July third week</td>
<td>3.28 (1.94)</td>
<td>5.66 (2.48)</td>
<td>7.20 (2.77)</td>
<td>6.76 (2.69)</td>
<td>7.30 (2.79)</td>
<td>0.84 (1.15)</td>
<td>2.80</td>
<td>1.76</td>
</tr>
<tr>
<td>August first week</td>
<td>3.86 (2.08)</td>
<td>5.35 (2.40)</td>
<td>7.24 (2.77)</td>
<td>7.64 (2.84)</td>
<td>5.32 (2.41)</td>
<td>0.88 (1.17)</td>
<td>3.10</td>
<td>1.87</td>
</tr>
<tr>
<td>SEm (±)</td>
<td>0.07</td>
<td>0.09</td>
<td>0.11</td>
<td>0.11</td>
<td>0.07</td>
<td>0.04</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>0.23</td>
<td>0.27</td>
<td>0.33</td>
<td>0.32</td>
<td>0.21</td>
<td>0.13</td>
<td>0.18</td>
<td>0.20</td>
</tr>
</tbody>
</table>

* Mean of four replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
4.2.4.8 Pod bugs

The lowest pod bugs incidence of 1.11 bugs per plant was recorded on crop sown at third week of June and highest during third week of July (2.10 bugs/plant), however it was statistically on par with sowing done at first week of August (2.00 bugs/plant) during the first year (Table 16).

During the second year, least incidence of pod bugs was noticed on crop sown during third week of June (1.67 bugs/plant), which was statistically on par with sowing done during first week of June (1.88 bugs/plant) and first week of July (2.00 bugs/plant) (Table 17).

4.2.4.9 Plume moth

During the first year, the lowest incidence of plum e moth (1.13 larvae/plant) was recorded on June first week sown crop which was on par with the crop sown at third week of June (1.44 larvae/plant). Later, the population was gradually increased with the advancement of sowing done at fortnightly interval and highest mean population of 2.18 larvae per plant was recorded on the crop sown during first week of August however, it was statistically on par with sowings done during third week of July (2.00 larvae/plant) and first week of July (1.80 larvae/plant) (Table 16). During the second year, least population density was recorded on the crop sown at first week of June (0.92 larvae/plant) which was on par with the crop sown at third week of June (1.10 larvae/plant) and first week of July (1.20 larvae/plant), whereas highest population was noticed on the crop sown at first week of August (1.87 larvae/plant) (Table 17).

4.2.5 Effect of dates of sowing on pod damage by pod borers in pigeonpea

The pigeonpea crop sown at fortnightly interval (June first week, June third week, July first week, July third week and August first week) to know the influence of different dates of sowing on pod damage by gram pod borer, plume moth and pod fly during 2011-12 and 2012-13 and the data are presented in table 18.

4.2.5.1 Gram pod borer

During the first year, the lowest pod damage of 45.60 per cent by gram pod borer at harvest was recorded on crop sown during first week of June, which was on par with the crop sown during third week of June (46.45%) and first week of July (48.24%). The crop sown during first week of August had maximum pod damage (90.22%), which was on par with the sowings done at third week of July (80.48%). Similar trend was noticed in the second year also by recording minimum pod damage (40.63%) on the crop sown during June first week and maximum (82.22%) on August first week sown crop.

The pooled analysis of two years data revealed the lowest pod damage (43.10%) by gram pod borer on a crop sown during first week of June, whereas the highest pod damage (86.22%) on the crop sown during first week of August (Table 18).

4.2.5.2 Plume moth

At harvest the lowest pod damage (21.69%) by plume moth was recorded on early sown crop (first week of June) and was on par with sowings done during third week of June (22.24%) and first week of July (24.44 %), whereas maximum pod damage was noticed on crop sown during first week of August (50.41 %) in the first year. Similar trend was observed during second year also and the pod damage ranged from 21.20 (first week of June) to 52.10 per cent (first week of August).

The pooled analysis of two season data also revealed similar trend in pod damage by plume moth with lowest pod damage (21.45 %) on a crop sown during first week of June and highest (51.26 %) on a crop sown during the first week of August (Table 18).

4.2.5.3 Pod fly

The pod fly inflicted minimum damage (4.92%) on the crop sown during first week of June, which was statistically on par with sowings done at third week of June (5.41%), whereas highest pod damage was noticed on the crop sown at first week of August (12.44%) in the first year. Similar trend was observed during second year also and the pod damage ranged from 4.90 (first week of June) to 13.32 per cent (first week of August).

The pooled data also indicated the similar trend with respect to the pod damage by pod fly and lowest pod damage (4.91 %) was recorded on a crop sown during first week of June and highest (12.88 %) on a crop sown during first week of August (Table 18).
Table 18: Effect of dates of sowing on pod damage and grain yield of pigeonpea due to pod borers

| Dates of sowing     | Gram pod borer |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| June first week     | 45.60          | 40.63 | 43.10 | 21.69 | 21.20 | 21.45 | 4.92   | 4.90   | 4.91   | 608    | 728   | 668   | 608    | 728   | 668   |
|                     | (42.46)a       | (39.55)a | (41.03)a | (27.67)a | (27.39)a | (27.56)a | (12.78)a | (12.77)a | (12.79)a |
| June third week     | 46.45          | 44.68 | 45.57 | 22.24 | 21.42 | 21.83 | 5.41   | 5.58   | 5.50   | 658    | 749   | 704   | 658    | 749   | 704   |
|                     | (42.95)a       | (41.93)a | (42.45)a | (28.07)a | (27.54)a | (27.85)a | (13.41)a | (13.63)b | (13.52)ab |
| July first week     | 48.24          | 45.44 | 46.84 | 24.44 | 24.60 | 24.52 | 7.21   | 6.10   | 6.66   | 580    | 680   | 630   | 580    | 680   | 630   |
|                     | (43.98)a       | (42.37)a | (43.17)a | (29.58)a | (29.71)a | (29.65)a | (15.56)b | (14.28)b | (14.93)b |
| July third week     | 80.48          | 82.48 | 81.48 | 40.73 | 45.66 | 43.20 | 10.54  | 10.23  | 10.38  | 160    | 190   | 175   | 160    | 190   | 175   |
|                     | (64.41)ab      | (65.28)b | (64.70)b | (39.64)b | (42.51)b | (41.08)b | (18.95)c | (18.64)c | (18.79)c |
| August first week   | 90.22          | 82.22 | 86.22 | 50.41 | 52.10 | 51.26 | 12.44  | 13.32  | 12.88  | 100    | 170   | 135   | 100    | 170   | 135   |
|                     | (72.00)bc      | (65.10)b | (68.24)b | (45.24)c | (46.21)d | (45.72)c | (20.64)d | (21.40)d | (21.03)d |
| SEm (±)             | 2.87           | 1.46  | 1.49  | 1.45  | 0.93  | 0.95  | 0.53   | 0.47   | 0.46   | 20.07  | 21.04 | 18.46 | 20.07  | 21.04 | 18.46 |
| CD (0.05)           | 8.83           | 4.50  | 4.60  | 4.48  | 2.87  | 2.92  | 1.64   | 1.46   | 1.43   | 61.83  | 64.83 | 56.87 | 61.83  | 64.83 | 56.87 |

* Mean of four replications
Values in parentheses are arc sine transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
4.2.6 Effect of dates of sowing on grain yield of pigeonpea

The grain yield of pigeonpea as influenced by different dates of sowing are presented in table 18.

The highest grain yield of 658 kg per hectare was obtained from crop sown during third week of June in the first year, which was statistically on par with sowings done during first week of June (608 kg/ha). The grain yield declined on the crop sown subsequently and lowest grain yield of 100 kg per hectare was recorded on the late sown crop during first week of August and was at par with sowings done during third week of July (160 kg/ha). Similar trend was noticed during the second year also and the grain yield ranged from 170 (first week of August) to 749 (third week of June) kg per hectare.

On the basis of pooled analysis of two season data, the highest grain yield (704 kg/ha) obtained from the crop sown during third week of June, whereas the lowest yield (135 kg/ha) was recorded from the crop sown during first week of August (table 18).

4.3 Varietal screening to identify the tolerance level of important cultivars

A total of 10 cultivars of pigeonpea were screened against major insect pests of pigeonpea under unprotected condition and results are presented in table 19.

4.3.1 Incidence of major insect pests on different cultivars

4.3.1.1 Leaf webber

Out of 10 cultivars screened against leaf webber during the first year (2011-12), the leaf webber incidence ranged from 2.87 (BSMR-736) to 5.43 webs per plant (ICPH-2671) however, differences among the cultivars was statistically non-significant. During the second year (2012-13), BSMR-736 registered significantly lowest webs (2.90 webs/plant) per plant which was statistically on par with ICPL-87119 (3.27 webs/plant), WRP-1 (3.70 web/plant), S-1 (3.73 webs/plant) and BRG-2 (3.87 webs/plant), whereas highest incidence was recorded in ICPH-2671 (6.03 webs/plant) which was on par with ICP-8863 (5.13 webs/plant), GC-11-39 (5.13 webs/plant) and TS-3(R) (5.07 webs/plant) (Table 19).

4.3.1.2 Spotted pod borer

The incidence of spotted pod borer varied significantly among the cultivars. During the first year, lowest incidence of spotted pod borer was observed in ICP-8863 (2.60 webs/plant) which was at par with WRP-1 (2.80 webs/plant), TS-3(R) (3.17 webs/plant) and BRG-2 (3.40 webs/plant). Significantly higher incidence was noticed in GC-11-39 with 10.23 webs per plant. Similar trend was observed during second year also and incidence was ranged between 2.83 (ICP-8863) to 9.43 webs per plant (GC-11-39) (Table 19).

4.3.1.3 Gram pod borer

During both the years of study, the incidence of gram pod borer was non-significant among the cultivars. The larval density during first year ranged between 3.53 (BSMR-736) to 7.13 larvae per plant (ICPH-2671). Similarly during second year, it ranged from 3.80 (BSMR-736) to 6.53 larvae per plant (ICPH-2671) (Table 19).

4.3.1.4 Bud weevil

The bud weevil incidence ranged from 4.87 to 9.80 weevils per plant among the different cultivars during the first year with least incidence on cultivar GC-11-39 (4.87 weevils/plant) and highest on ICPH-2671 (9.80 weevils/plant) which was on par with ICPL-87119 (8.40 weevils/plant), ICP-8863 (7.83 weevils/plant), BSMR-736 (8.30 weevils/plant), TS-3(R) (8.47 weevils/plant), WRP-1 (7.60 weevils/plant), S-1 (9.57 weevils/plant), BRG-2 (8.30 weevils/plant) and HY-3C (7.73 weevils/plant). During second year, the mean population density ranged from 5.03 (GC-11-39) to 9.62 weevils per plant (ICPH-2671) however, the differences among the cultivars was not significant (Table 19).

4.3.1.5 Pod bugs

During the first year, least population (0.76 bugs/plant) of pod bugs was registered by GC-11-39 cultivar, which was on par with HY-3C (1.08 bugs/plant). The cultivars ICP-8863 (1.77 bugs/plant),
Table 19: Evaluation of pigeonpea cultivars against major insect pests during 2011-12 and 2012-13

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Leaf webber (webs/plant)</th>
<th>Spotted pod borer (webs/plant)</th>
<th>Gram pod borer</th>
<th>Bud weevil</th>
<th>Pod bug</th>
<th>Plume moth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11-12</td>
<td>12-13</td>
<td>Mean</td>
<td>11-12</td>
<td>12-13</td>
<td>Mean</td>
</tr>
<tr>
<td>ICPL-87119</td>
<td>3.17 (1.91)</td>
<td>3.27 (1.93)</td>
<td>3.22</td>
<td>5.85 (2.52)</td>
<td>5.53 (2.45)</td>
<td>5.69</td>
</tr>
<tr>
<td>ICP-8863</td>
<td>4.77 (2.28)</td>
<td>5.13 (2.37)</td>
<td>4.95</td>
<td>2.60 (1.76)</td>
<td>2.83 (1.82)</td>
<td>2.72</td>
</tr>
<tr>
<td>BSMR-736</td>
<td>2.87 (1.81)</td>
<td>2.90 (1.84)</td>
<td>2.88</td>
<td>6.43 (2.63)</td>
<td>7.07 (2.74)</td>
<td>6.75</td>
</tr>
<tr>
<td>GC-11-39</td>
<td>4.57 (2.24)</td>
<td>5.13 (2.37)</td>
<td>4.85</td>
<td>10.23 (3.27)</td>
<td>9.43 (3.15)</td>
<td>9.83</td>
</tr>
<tr>
<td>TS-3 (R)</td>
<td>5.03 (2.35)</td>
<td>5.07 (2.36)</td>
<td>5.05</td>
<td>3.17 (1.91)</td>
<td>3.80 (2.06)</td>
<td>3.48</td>
</tr>
<tr>
<td>WRP-1</td>
<td>4.57 (2.25)</td>
<td>3.70 (2.05)</td>
<td>4.13</td>
<td>2.80 (1.80)</td>
<td>3.03 (1.87)</td>
<td>2.92</td>
</tr>
<tr>
<td>S-1</td>
<td>2.97 (1.85)</td>
<td>3.73 (2.06)</td>
<td>3.35</td>
<td>6.10 (2.57)</td>
<td>7.10 (2.74)</td>
<td>6.60</td>
</tr>
<tr>
<td>BRG-2</td>
<td>4.83 (2.29)</td>
<td>3.87 (2.09)</td>
<td>4.35</td>
<td>3.40 (1.96)</td>
<td>3.80 (2.07)</td>
<td>3.60</td>
</tr>
<tr>
<td>HY-3C</td>
<td>5.07 (2.32)</td>
<td>4.33 (2.10)</td>
<td>4.70</td>
<td>3.87 (2.09)</td>
<td>4.00 (2.12)</td>
<td>3.93</td>
</tr>
<tr>
<td>ICPH-2671</td>
<td>5.43 (2.41)</td>
<td>6.03 (2.54)</td>
<td>5.73</td>
<td>4.87 (2.92)</td>
<td>4.53 (2.24)</td>
<td>4.70</td>
</tr>
<tr>
<td>SEm ( )</td>
<td>0.20</td>
<td>0.09</td>
<td>-</td>
<td>0.10</td>
<td>0.13</td>
<td>-</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>NS</td>
<td>0.25</td>
<td>-</td>
<td>0.31</td>
<td>0.38</td>
<td>-</td>
</tr>
</tbody>
</table>

* Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
BSMR-736 (1.83 bugs/plant), TS-3(R) (1.60 bugs/plant), S-1 (1.63 bugs/plant), ICPH-2671 (1.53 bugs/plant) harboured higher population of pod bugs and were found on par with each other. The mean population of pod bugs during second year ranged between 0.81 (GC-11-39) and 2.40 bugs per plant (BSMR-736) however, the differences among the cultivars were non-significant (Table 19).

4.3.1.6 Plume moth

The cultivar, GC-11-39 recorded lowest incidence (0.87 larvae/plant) of plume moth during the first year, which was on par with ICP-8863 (1.23 larvae/plant), TS-3(R) (1.37 larvae/plant), WRP-1 (1.47 larvae/plant), BRG-2 (1.10 larvae/plant), HY-3C (1.53 larvae/plant) and ICPH-2671 (1.77 larvae/plant) whereas, the cultivar, S-1 recorded higher population (3.23 larvae/plant) of plume moth and found on par with ICPL-87119 (2.70 larvae/plant) and BSMR-736 (2.80 larvae/plant). During the second year, the least population density of 0.33 larvae per plant was registered by GC-11-39 cultivar and found superior over rest of the cultivars. Further rest of the cultivars were inferior to GC-11-39 and found on par with each other (Table 19).

4.3.2 Pod damage by pod borers on different cultivars

The incidence of pod borers (gram pod borer, plume moth and pod fly) on different cultivars was assessed at harvest and the data are presented in table 20.

4.3.2.1 Gram pod borer

During the first year, the pod damage at harvest by gram pod borer was ranged from 50.78 (BSMR-736) to 77.03 per cent (ICPH-2671) however, the differences among the cultivars were non-significant. During the second year, the cultivar BSMR-736 registered lowest pod damage of 53.34 per cent, which was on par with S-1 (56.93%), WRP-1 (59.67%) and BRG-2 (60.91%), whereas the cultivar ICPH-2671 recorded significantly highest pod damage (75.48%) (Table 20).

4.3.2.2 Plume moth

The cultivar, GC-11-39 recorded least pod damage of 15.62 per cent which was on par with BRG-2 (17.78%), TS-3(R) (17.90%), and WRP-1 (18.01%) whereas, BSMR-736 recorded significantly higher pod damage (22.07%) during first year. During second year, the per cent pod damage ranged from 17.08 (GC-11-39) to 21.32 (BSMR-736) however, the performance of cultivars was non-significant (Table 20).

4.3.2.3 Pod fly

The pod fly inflicted minimum of 5.45 per cent pod damage on GC-11-39, whereas significantly highest pod damage (17.24%) was noticed on S-1 and was statistically on par with ICPH-2671 (14.97%), BSMR-736 (15.58%) and ICPL-87119 (15.97%) during first year. The pod fly damage during second year was least on GC-11-39 (4.52%) whereas, it was significantly highest (16.53%) on S-1 and statistically on par with ICP-8863 (11.78%), WRP-1 (12.20%), BRG-2 (13.91%), BSMR-736 (14.41%), ICPH-2671 (15.77%) and ICPL-87119 (15.88%) (Table 20).

4.4 Efficacy of various conventional insecticides against major insect pests of pigeonpea

4.4.1 Effect of various treatments on pest incidence

The data on efficacy of various treatments against major insect pests of pigeonpea during first (2011-12) and second year (2012-13) under field condition recorded at a day before spray, three, seven and fourteen days after first, second and third spray are as under.

4.4.1.1 Spotted pod borer, *Maruca vitrata* (Geyer)

The results on efficacy of various treatments against spotted pod borer, *M. vitrata* recorded during first and second year has been presented in table 21 and 22.

4.4.1.1.1 First year (2011-12)

At first spray

The pre-count recorded at a day before spray indicated non-significant difference between various treatments and the incidence ranged from 2.80 to 3.18 webs per plant (Table 21).
Table 20: Per cent pod damage by pod borers in different pigeonpea cultivars during 2011-12 and 2012-13

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Gram pod borer</th>
<th>Plume moth</th>
<th>Pod fly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011-12</td>
<td>2012-13</td>
<td>Mean</td>
</tr>
<tr>
<td>ICPL-87119</td>
<td>66.20 (54.61)</td>
<td>64.27 (53.31)</td>
<td>65.24</td>
</tr>
<tr>
<td>ICP-8863</td>
<td>68.18 (55.89)</td>
<td>65.28 (53.93)</td>
<td>66.73</td>
</tr>
<tr>
<td>BSMR-736</td>
<td>50.78 (45.46)</td>
<td>53.34 (46.92)</td>
<td>52.06</td>
</tr>
<tr>
<td>GC-11-39</td>
<td>72.66 (58.70)</td>
<td>68.33 (55.83)</td>
<td>70.50</td>
</tr>
<tr>
<td>TS-3 (R)</td>
<td>62.52 (52.27)</td>
<td>66.41 (54.60)</td>
<td>64.46</td>
</tr>
<tr>
<td>WRP-1</td>
<td>59.04 (50.27)</td>
<td>59.67 (50.60)</td>
<td>59.35</td>
</tr>
<tr>
<td>S-1</td>
<td>58.30 (49.84)</td>
<td>56.93 (49.00)</td>
<td>57.61</td>
</tr>
<tr>
<td>BRG-2</td>
<td>62.20 (52.17)</td>
<td>60.91 (51.33)</td>
<td>61.56</td>
</tr>
<tr>
<td>HY3C</td>
<td>70.99 (57.72)</td>
<td>73.37 (59.02)</td>
<td>72.18</td>
</tr>
<tr>
<td>ICPH-2671</td>
<td>77.03 (61.55)</td>
<td>75.48 (60.38)</td>
<td>76.26</td>
</tr>
<tr>
<td>SEm (±)</td>
<td>3.28</td>
<td>1.78</td>
<td>-</td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>NS</td>
<td>5.29</td>
<td>-</td>
</tr>
</tbody>
</table>

* Mean of three replications  
Values in parentheses are arc sine transformations  
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
At third day after spray (DAS), the treatments $T_2$ and $T_8$ found significantly superior by recording 0.12 and 0.17 webs per plant, respectively which were on par with each other. Further significantly higher incidence (4.53 webs/plant) was recorded in untreated check.

At seventh DAS, the treatments $T_2$ recorded the least incidence of 0.10 webs per plant, which was superior over all other treatments. The next best treatment proved to be $T_8$ (0.62 webs/plant), whereas untreated check recorded higher incidence of 7.60 webs per plant.

Similar trend was followed at 14 DAS and the incidence ranged between 1.47 webs per plant ($T_2$) to 9.55 webs per plant ($T_9$).

At second spray

At third DAS, the treatments $T_2$ and $T_8$ found significantly superior by recording 0.12 and 0.17 webs per plant, respectively which were on par with each other. Further significantly higher incidence (4.53 webs/plant) was recorded in untreated check.

At seventh DAS, the treatments $T_2$ recorded the least incidence of 0.10 webs per plant, which was superior over all other treatments. The next best treatment proved to be $T_8$ (0.62 webs/plant), whereas untreated check recorded higher incidence of 7.60 webs per plant.

At second spray

At third DAS, the treatments $T_2$ and $T_8$ found significantly superior by recording 0.12 and 0.17 webs per plant, respectively which were on par with each other. Further significantly higher incidence (4.53 webs/plant) was recorded in untreated check.

At seventh DAS, the treatments $T_2$ recorded the least incidence of 0.10 webs per plant, which was superior over all other treatments. The next best treatment proved to be $T_8$ (0.62 webs/plant), whereas untreated check recorded higher incidence of 7.60 webs per plant.

Similar trend was followed at 14 DAS and the incidence ranged between 1.47 webs per plant ($T_2$) to 9.55 webs per plant ($T_9$).

At second spray

At third DAS, the treatments $T_3$ and $T_5$ registered least incidence with 1.10 and 1.25 webs per plant, respectively and were on par with each other whereas, significantly higher incidence (8.41 webs/plant) was recorded by $T_9$ treatment (Table 21).

At seventh DAS, similar trend was observed by recording significantly lowest incidence of 1.04 and 1.11 webs per plant in treatments $T_3$ and $T_5$, respectively which were on par with each other. However, the treatment $T_9$ differed with these treatments by recording 6.52 webs per plant.

Similar trend as that of third and seventh DAS was observed at 14 DAS also and least incidence was noticed in $T_3$ (0.92 webs/plant) and $T_5$ (0.81 webs/plant), which were on par with each other whereas significantly higher incidence (6.37 webs/plant) was recorded in $T_9$.

At third spray

At second spray, there was overall decline in incidence of spotted pod borer irrespective of treatments (Table 21). The treatment, $T_9$ recorded higher incidence of 4.33 and 3.00 webs per plant at third and seventh DAS, respectively followed by $T_1$ with 2.92 and 0.82 webs plant, respectively. However, there was no incidence of leaf webber in rest of the treatments.

4.4.1.1.2 Second year (2012-13)

At first spray

The pre-treatment count of spotted pod borer incidence a day before spray did not differ significantly among the treatments and further, the incidence varied from 4.60 to 4.87 webs per plant (Table 22).

At third DAS, significantly lesser incidence was noticed in treatments $T_9$ and $T_2$ (0.20 and 0.27 webs/plant), which were statistically on par with each other. The next best treatments were $T_4$ (1.30 webs/plant), $T_6$ (1.13 webs/plant) and $T_6$ (1.30 webs/plant), which were on par with each other whereas $T_9$ recorded significantly higher incidence (4.80 webs/plant).

Similar trend was observed at seventh DAS, wherein $T_2$ and $T_8$ found to be significantly superior over all other treatments. At seventh DAS, the treatments $T_2$ and $T_8$ found superior by recording least incidence of 0.20 and 0.27 webs per plant, respectively whereas $T_9$ recorded higher incidence of 7.73 webs per plant.

Like previous observations, the treatments $T_2$ (0.93 webs/plant) and $T_8$ (1.03 webs/plant) proved to be superior over all other treatments at 14 DAS whereas $T_9$ recorded higher incidence of 9.55 webs per plant.

At second spray

At third DAS, significantly lower incidence was recorded in treatment $T_9$ (0.90 webs/plant) and $T_8$ (0.93 webs/plant), which was statistically on par with each other and the higher incidence of 9.13 webs per plant was noticed in treatment $T_9$ (Table 22).

Similar trend was observed at seventh and 14 DAS, wherein $T_3$ (1.03 and zero webs/plant) and $T_5$ treatments (0.85 and zero webs/plant) found to be significantly superior over all other treatments, which were statistically on par with each other. Significantly higher incidence was again noticed in treatment $T_9$ with 7.40 and 6.87 webs per plant at seventh and 14 DAS, respectively.
Table 21: Efficacy of various treatments against spotted pod borer, *Maruca vitrata* (Geyer) in pigeonpea during 2011-2012

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>DBS</th>
<th>3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
<th>3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
<th>3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>3.18</td>
<td>4.12</td>
<td>6.34</td>
<td>8.23</td>
<td>6.50</td>
<td>5.52</td>
<td>4.15</td>
<td>2.92</td>
<td>0.82</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.92)</td>
<td>(2.15)</td>
<td>(2.61)</td>
<td>(2.95)</td>
<td>(2.65)</td>
<td>(2.45)</td>
<td>(2.16)</td>
<td>(1.85)</td>
<td>(1.15)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - <em>HaNPV</em> (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>2.80</td>
<td>0.12</td>
<td>0.10</td>
<td>1.47</td>
<td>3.50</td>
<td>3.47</td>
<td>2.83</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.82)</td>
<td>(0.79)</td>
<td>(0.77)</td>
<td>(1.40)</td>
<td>(2.00)</td>
<td>(1.99)</td>
<td>(1.82)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>3.12</td>
<td>1.80</td>
<td>3.17</td>
<td>3.90</td>
<td>1.10</td>
<td>1.04</td>
<td>0.92</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.90)</td>
<td>(1.52)</td>
<td>(1.91)</td>
<td>(2.10)</td>
<td>(1.26)</td>
<td>(1.24)</td>
<td>(1.19)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - <em>HaNPV</em> (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>2.90</td>
<td>0.89</td>
<td>1.14</td>
<td>2.88</td>
<td>3.70</td>
<td>3.26</td>
<td>2.78</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.84)</td>
<td>(1.18)</td>
<td>(1.28)</td>
<td>(1.84)</td>
<td>(2.05)</td>
<td>(1.94)</td>
<td>(1.81)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T5</td>
<td>Quinophos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>3.00</td>
<td>1.08</td>
<td>1.18</td>
<td>2.67</td>
<td>1.25</td>
<td>1.11</td>
<td>0.81</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.87)</td>
<td>(1.26)</td>
<td>(1.30)</td>
<td>(1.78)</td>
<td>(1.32)</td>
<td>(1.27)</td>
<td>(1.14)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T6</td>
<td>DDVP 76 EC (0.5 ml/l) - <em>Bacillus thuringiensis</em> (2 kg/ha) - Emamectin benzoate 5 SC (0.2 g/l)</td>
<td>3.12</td>
<td>1.00</td>
<td>2.00</td>
<td>2.88</td>
<td>4.00</td>
<td>3.60</td>
<td>3.04</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.90)</td>
<td>(1.22)</td>
<td>(1.58)</td>
<td>(1.84)</td>
<td>(2.12)</td>
<td>(2.02)</td>
<td>(1.88)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T7</td>
<td>Acephate 75 SP (1 g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>2.94</td>
<td>2.10</td>
<td>2.86</td>
<td>3.12</td>
<td>2.52</td>
<td>3.19</td>
<td>2.08</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.85)</td>
<td>(1.61)</td>
<td>(1.83)</td>
<td>(1.90)</td>
<td>(1.73)</td>
<td>(1.92)</td>
<td>(1.60)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>3.11</td>
<td>0.17</td>
<td>0.62</td>
<td>1.78</td>
<td>4.43</td>
<td>3.82</td>
<td>3.13</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.90)</td>
<td>(0.82)</td>
<td>(1.05)</td>
<td>(1.51)</td>
<td>(2.22)</td>
<td>(2.08)</td>
<td>(1.91)</td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>2.95</td>
<td>4.53</td>
<td>7.60</td>
<td>9.55</td>
<td>8.41</td>
<td>6.52</td>
<td>6.37</td>
<td>4.33</td>
<td>3.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.86)</td>
<td>(2.24)</td>
<td>(2.85)</td>
<td>(3.17)</td>
<td>(2.99)</td>
<td>(2.65)</td>
<td>(2.62)</td>
<td>(2.20)</td>
<td>(1.87)</td>
<td>(0.71)</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are square root transformations
DBS: Day before spraying, DAS: Days after spraying
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
Table 22: Efficacy of various treatments against spotted pod borer, *Maruca vitrata* (Geyer) in pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBS</td>
<td>3 DAS</td>
<td>7 DAS</td>
<td>14 DAS</td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>4.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.53&lt;sup&gt;(2.19)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.47&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - <em>Ha</em>NPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>4.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.27&lt;sup&gt;(0.87)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt;</td>
<td>Nimbecidine 0.03 EC (3 ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>4.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.27&lt;sup&gt;(1.94)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt;</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - <em>Ha</em>NPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>4.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.40&lt;sup&gt;(1.38)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;5&lt;/sub&gt;</td>
<td>Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>4.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.40&lt;sup&gt;(1.38)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.80&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;6&lt;/sub&gt;</td>
<td>Bacillus thuringiensis (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
<td>4.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.80&lt;sup&gt;(1.52)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;7&lt;/sub&gt;</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>4.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.13&lt;sup&gt;(1.62)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.80&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt;</td>
<td>Dicofol 18.5 EC (25 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>4.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.03&lt;sup&gt;(0.87)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.33&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt;</td>
<td>Untreated check</td>
<td>4.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.73&lt;sup&gt;(3.17)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>9.55&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Mean of three replications *
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

DBS: Day before spraying, DAS: Days after spraying
At third spray

After second spray, there was gradual decline in the incidence of spotted pod borer irrespective of the treatments (Table 22).

The higher incidence of 3.80 and 1.83 webs per plant was observed in treatment T9 at third and seventh DAS, respectively, followed by T1 with 3.59 and 1.53 webs per plant, respectively. Further, there was no incidence of leaf webber in rest of the treatments.

4.4.1.2 Gram pod borer, *Helicoverpa armigera* (Hubner)

The results on efficacy of various treatments against Gram pod borer, *H. armigera* during first and second year study period has been presented in table 23 and 24.

4.4.1.2.1 First year (2011-12)

At first spray

At a day prior to the imposition of treatments the population of gram pod borer among various treatments was statistically non significant and population ranged between 1.67 to 2.26 larvae per plant among the treatments (Table 23).

At third DAS, the least population of gram pod borer was registered by treatments T2 and T8 with 0.22 and 0.26 larvae per plant, respectively and were on par with each other. The next best treatment was T4 (0.95 larvae/plant), which was statistically on par with T5 (1.20 larvae/plant).

Similar trend was observed at seventh and 14 DAS, wherein the treatments T2 (0.24 and 0.66 larvae/plant) and T8 (0.32 and 0.58 larvae/plant) performed better over remaining treatments, whereas highest population density of 4.25 and 4.85 larvae per plant was observed in T9 at 7 and 14 DAS, respectively.

At second spray

At third DAS, the treatments T3 and T5 recorded significantly lowest incidence of 1.06 and 0.96 larvae per plant, respectively, which were statistically on par with each other. The next best treatment was T6 which recorded 1.35 larvae per plant. Further, significantly higher incidence was recorded by T9 treatment (5.50 larvae/plant) (Table 23).

Least incidence of 0.56 larvae per plant was observed at seventh DAS in T6 treatment, which was statistically on par with T4 (0.75 larvae/plant), whereas T9 recorded significantly higher population (6.37 larvae/plant) of gram pod borer.

At 14 DAS, the treatments T2 and T4 were found superior over rest of the treatments by recording 0.82 and 0.65 larvae per plant, respectively and were on par with each other. Significantly higher larvae were found in the treatment T9 (6.80 larvae/plant), which was statistically on par with T1.

At third spray

After third spray, there was overall decline in population density of gram pod borer among the treatments (Table 23).

Significantly lower incidence of 0.20 larvae per plant was recorded in the treatment T3 at third DAS which was statistically on par with the treatment T4 (0.26 larvae/plant), T6 (0.24 larvae/plant), T7 (0.24 larvae/plant) and T8 (0.25 larvae/plant), whereas significantly higher population was recorded in T9 (8.42 larvae/plant).

At seventh DAS, the pest population was reduced to 0.51, 0.28, 0.30, 0.32, 0.37 and 0.45 larvae per plant in the treatments T2, T3, T4, T6, T7 and T8, respectively and were on par with each other. Significantly higher larval count (5.22 larvae/plant) was recorded in treatment T9.

The treatments T3, T4, T6, and T7 maintained their superiority over other treatments by reducing the larval density (0.42, 0.44, 0.48 and 0.50 larvae per plant) at 14 DAS and were statistically on par with each other, whereas T9 registered significantly higher larval density of 4.68 larvae per plant (Table 23).
### Table 23: Efficacy of various treatments against gram pod borer, *Helicoverpa armigera* (Hubner) on pigeonpea during 2011-2012

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>DBS 3 DAS</th>
<th>7 DAS</th>
<th>14DAS</th>
<th>3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
<th>3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
<th>3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>2.12 (1.62)^a</td>
<td>2.82 (1.82)^d</td>
<td>3.13 (1.91)^c</td>
<td>4.17 (2.16)^b</td>
<td>4.40 (2.21)^b</td>
<td>5.30 (2.41)^a</td>
<td>6.38 (2.62)^d</td>
<td>7.39 (2.80)^d</td>
<td>3.71 (2.05)^f</td>
<td>3.27 (1.34)^d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>1.93 (1.56)^a</td>
<td>0.22 (0.80)^a</td>
<td>0.24 (0.86)^a</td>
<td>0.66 (1.08)^a</td>
<td>2.60 (1.76)^b</td>
<td>0.90 (1.18)^b</td>
<td>0.82 (1.15)^a</td>
<td>0.40 (0.95)^b</td>
<td>0.51 (1.01)^a</td>
<td>0.81 (1.14)^bc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>Nimbicidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>1.67 (1.47)^a</td>
<td>1.46 (1.40)^c</td>
<td>1.60 (1.44)^b</td>
<td>1.80 (1.52)^d</td>
<td>1.06 (1.25)^a</td>
<td>1.30 (1.34)^g</td>
<td>1.37 (1.37)^b</td>
<td>0.20 (0.84)^a</td>
<td>0.28 (0.88)^b</td>
<td>0.42 (0.96)^a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>1.93 (1.56)^a</td>
<td>0.95 (1.20)^b</td>
<td>1.07 (1.25)^c</td>
<td>1.20 (1.30)^b</td>
<td>2.23 (1.65)^d</td>
<td>0.75 (1.12)^ab</td>
<td>0.65 (1.07)^a</td>
<td>0.26 (0.87)^a</td>
<td>0.30 (0.90)^a</td>
<td>0.44 (0.97)^a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T5</td>
<td>Quinolophos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>1.82 (1.52)^a</td>
<td>1.20 (1.30)^c</td>
<td>1.43 (1.38)^b</td>
<td>1.47 (1.40)^c</td>
<td>0.96 (1.21)^a</td>
<td>1.13 (1.28)^b</td>
<td>1.20 (1.30)^c</td>
<td>0.78 (1.13)^c</td>
<td>0.87 (1.17)^b</td>
<td>0.97 (1.21)^c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6</td>
<td>DDVP 76 EC (0.5 ml/l) - Bacillus thuringiensis (2 kg/ha) - Emanectin benzoate 5 SG (0.2 g/l)</td>
<td>2.26 (1.66)^a</td>
<td>1.27 (1.33)^c</td>
<td>1.30 (1.34)^b</td>
<td>1.40 (1.40)^c</td>
<td>1.35 (1.36)^b</td>
<td>0.56 (1.03)^ab</td>
<td>1.17 (1.29)^b</td>
<td>0.24 (0.86)^a</td>
<td>0.32 (0.91)^a</td>
<td>0.48 (0.99)^a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T7</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>1.90 (1.55)^a</td>
<td>1.33 (1.35)^c</td>
<td>1.40 (1.38)^b</td>
<td>1.45 (1.40)^c</td>
<td>2.08 (1.61)^d</td>
<td>1.20 (1.30)^c</td>
<td>1.27 (1.33)^c</td>
<td>0.24 (0.86)^a</td>
<td>0.37 (0.93)^a</td>
<td>0.50 (1.00)^a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>2.01 (1.54)^a</td>
<td>0.26 (0.87)^a</td>
<td>0.32 (0.90)^a</td>
<td>0.58 (1.04)^a</td>
<td>1.90 (1.55)^b</td>
<td>2.43 (1.71)^d</td>
<td>3.17 (1.91)^c</td>
<td>0.25 (0.87)^a</td>
<td>0.45 (0.98)^b</td>
<td>0.76 (1.12)^b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>1.94 (1.56)^a</td>
<td>3.50 (2.00)^b</td>
<td>4.25 (2.17)^d</td>
<td>4.85 (2.31)^d</td>
<td>5.50 (2.45)^b</td>
<td>6.37 (2.62)^d</td>
<td>6.80 (2.70)^d</td>
<td>8.42 (2.99)^g</td>
<td>5.22 (2.39)^d</td>
<td>4.68 (2.27)^e</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SEm± NS 0.04 0.03 0.07 0.02 0.03 0.03 0.04 0.05 0.05 0.07
CD (0.05) NS 0.10 0.20 0.06 0.08 0.10 0.13 0.09 0.14 0.07

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

**DBS:** Day before spraying, **DAS:** Days after spraying

---

**Table Notes:**
- **DBS:** Day before spraying
- **DAS:** Days after spraying
- **SEm±:** Standard error of the mean ± standard deviation
- **CD (0.05):** Critical difference at a significance level of 0.05
- **Values in parentheses are square root transformations**
- **In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.**
Table 24: Efficacy of various treatments against gram pod borer, *Helicoverpa armigera* (Hubner) on pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DBS 3 DAS</td>
<td>7 DAS</td>
<td>14 DAS</td>
</tr>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>1.87 (1.53)</td>
<td>3.33 (1.96)</td>
<td>3.93 (2.10)</td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>1.90 (1.54)</td>
<td>0.20 (0.84)</td>
<td>0.27 (0.87)</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>1.80 (1.52)</td>
<td>1.20 (1.30)</td>
<td>1.30 (1.34)</td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>2.03 (1.59)</td>
<td>1.13 (1.28)</td>
<td>1.13 (1.28)</td>
</tr>
<tr>
<td>T5</td>
<td>Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenphos 50 EC (2 ml/l)</td>
<td>2.07 (1.66)</td>
<td>0.90 (1.18)</td>
<td>1.00 (1.22)</td>
</tr>
<tr>
<td>T6</td>
<td>DDVP 76 EC (0.5 ml/l) - Bacillus thuringiensis (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
<td>1.90 (1.55)</td>
<td>1.13 (1.27)</td>
<td>1.20 (1.30)</td>
</tr>
<tr>
<td>T7</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>2.08 (1.60)</td>
<td>1.20 (1.30)</td>
<td>1.73 (1.49)</td>
</tr>
<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>2.07 (1.60)</td>
<td>0.27 (0.87)</td>
<td>0.33 (0.91)</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>2.03 (1.59)</td>
<td>3.80 (2.07)</td>
<td>3.90 (2.10)</td>
</tr>
<tr>
<td></td>
<td>SEm±</td>
<td>0.07</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>CD (0.05)</td>
<td>NS</td>
<td>0.11</td>
<td>0.11</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
DBS: Day before spraying, DAS: Days after spraying
4.4.1.2.2 Second year (2012-13)

At first spray

The population of gram pod borer in all the treatments was uniform at a day prior to imposition of treatments as indicated by the non significant difference among various treatments and ranged between 1.80 and 2.08 larvae per plant (Table 24).

At third DAS, T₂ and T₆ treatments registered least population of 0.20 and 0.27 gram pod borer larvae per plant, respectively and were statistically on par with each other. Significantly higher larval population (3.80 larvae/plant) was observed in T₉ and was on par with treatment T₁ (3.33 larvae/plant).

Similar trend was noticed at seventh and 14 DAS, wherein T₂ (0.27 and 0.58 larvae/plant) and T₆ (0.33 and 0.62 larvae/plant) treatments recorded least population of gram pod borer. Significantly higher population was noticed in T₉ with 3.90 and 4.30 larvae per plant at seventh and 14 DAS, respectively. However, it was statistically on par with treatment T₁.

At second spray

At third DAS, T₂ and T₄ recorded significantly least larval population of 0.27 and 0.33 larvae per plant, respectively which were statistically on par with each other. Significantly higher larval density of 6.93 larvae per plant, which was being on par with T₁ (6.60 larvae/plant).

At 14 DAS, the treatments T₂ and T₄ recorded significantly least larval population of 0.47 and 0.33 larvae per plant, respectively which were statistically on par with each other. The treatment T₉ registered higher larval density of 7.67 and was on par with T₁ (7.13 larvae/plant).

At third spray

At third DAS, the treatments T₂, T₃, T₄, T₆, T₇ and T₈ were proved their superiority by recording 0.33, 0.20, 0.27, 0.24, 0.25 and 0.28 larvae per plant, respectively and were statistically on par with each other. Significantly higher larval density was observed in T₉ (9.73 larvae/plant) (Table 24).

Similar trend was noticed at seventh DAS with larval density ranging from 0.23 in T₃ to 7.88 larvae per plant in T₉ treatments.

Least larval count (0.36, 0.46 and 0.45 larvae/plant) was observed in treatments T₃, T₆ and T₇ at 14 DAS and significantly higher larval density of 4.56 larvae per plant was observed in T₉ treatment.

4.4.1.3 Plume moth, *Exelastis atomosa* (May.)

The results on efficacy of various treatments against plume moth during first and second year of study have been presented in tables 25 and 26.

4.4.1.3.1 First year (2011-12)

At first spray

Significantly higher incidence (0.40 larvae/plant) of plume moth was recorded in treatment T₉ at seventh DAS followed by T₁ (0.27 larvae/plant). Rest of the treatments recorded no incidence of plume moth during the period (Table 25).

At 14 DAS, there was no incidence of plume moth in the treatments T₂, T₆, T₇ and T₈, whereas significantly higher incidence was observed in the treatment T₉ (1.67 larvae/plant).

At second spray

At third DAS, least population of 0.10 and 0.21 larvae per plant was noticed in treatments T₅ and T₉ respectively, which were statistically on par with each other. Significantly higher incidence of 1.90 larvae per plant was observed in the treatment T₉ and was on par with T₁ (1.87 larvae/plant) (Table 25).

At seventh and 14 DAS, the treatments T₃ (0.20 and 0.25 larvae/plant) and T₅ (0.22 and 0.25 larvae/plant) respectively recorded least population of plume moth. The treatment T₉ registered
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DBS</td>
<td>3 DAS</td>
<td>7 DAS</td>
<td>14 DAS</td>
<td>3 DAS</td>
<td>7 DAS</td>
</tr>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.27 (0.87)</td>
<td>0.66 (1.08)</td>
<td>1.87 (1.54)</td>
<td>2.90 (1.84)</td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.28 (0.87)</td>
<td>0.75 (1.12)</td>
<td>1.20 (1.33)</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - DDPV 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.27 (0.87)</td>
<td>0.21 (0.84)</td>
<td>0.20 (0.84)</td>
<td>0.25 (0.87)</td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.18 (0.82)</td>
<td>0.35 (0.92)</td>
<td>1.10 (1.26)</td>
<td>1.78 (1.50)</td>
</tr>
<tr>
<td>T5</td>
<td>Quinolphos 25 EC (2 ml/l) - DDPV 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.14 (0.80)</td>
<td>0.10 (0.77)</td>
<td>0.22 (0.85)</td>
<td>0.25 (0.86)</td>
</tr>
<tr>
<td>T6</td>
<td>DDPV 76 EC (0.5 ml/l) - Bacillus thuringiensis (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.50 (1.00)</td>
<td>1.20 (1.30)</td>
<td>1.90 (1.55)</td>
</tr>
<tr>
<td>T7</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.40 (0.95)</td>
<td>0.51 (1.05)</td>
<td>0.61 (1.05)</td>
</tr>
<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.35 (0.92)</td>
<td>1.20 (1.30)</td>
<td>1.77 (1.50)</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.40 (0.95)</td>
<td>1.67 (1.47)</td>
<td>1.90 (1.55)</td>
<td>2.20 (1.64)</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
DBS: Day before spraying, DAS: Days after spraying
Table 26: Efficacy of various treatments against plume moth, *Exelastis atomosa* (May.) on pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
<th>II spray</th>
<th>III spray</th>
<th>IV spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DBS</td>
<td>3 DAS</td>
<td>7 DAS</td>
<td>14 DAS</td>
<td>3 DAS</td>
<td>7 DAS</td>
</tr>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>0.00</td>
<td>0.00</td>
<td>0.87</td>
<td>1.17</td>
<td>1.27</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71)</td>
<td>(1.17) b</td>
<td>(1.29) d</td>
<td>(1.33) g</td>
<td>(1.52) e</td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - <em>HaNPV</em> (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.60</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.71) c</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.33</td>
<td>0.20</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.91) c</td>
<td>(0.84) d</td>
<td>(0.87) a</td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - <em>HaNPV</em> (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.20</td>
<td>0.87</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.84) b</td>
<td>(1.17) c</td>
<td>(1.35) c</td>
</tr>
<tr>
<td>T5</td>
<td>Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.27</td>
<td>0.23</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.87) b</td>
<td>(0.85) a</td>
<td>(0.93) a</td>
</tr>
<tr>
<td>T6</td>
<td>DDVP 76 EC (0.5 ml/l) - <em>Bacillus thuringiensis</em> (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.67</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(1.08) b</td>
<td>(1.47) b</td>
</tr>
<tr>
<td>T7</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.22</td>
<td>0.56</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.85) b</td>
<td>(1.03) b</td>
<td>(1.11) b</td>
</tr>
<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.93</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(0.71) a</td>
<td>(1.20) c</td>
<td>(1.55) c</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>0.00</td>
<td>0.00</td>
<td>0.93</td>
<td>1.07</td>
<td>2.20</td>
<td>2.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.71)</td>
<td>(1.20) b</td>
<td>(1.25) d</td>
<td>(1.64) a</td>
<td>(1.67) l</td>
<td>(1.82) l</td>
</tr>
<tr>
<td></td>
<td>SEm±</td>
<td>--</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>CD (0.05)</td>
<td>--</td>
<td>0.04</td>
<td>0.06</td>
<td>0.08</td>
<td>0.11</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*Mean of three replications

Values in parentheses are square root transformations

*In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

DBS: Day before spraying, DAS: Days after spraying
significantly higher population of 2.20 larvae per plant at seventh DAS, whereas both T₉ (3.27 larvae/plant) and T₁ (3.17 larvae/plant) recorded higher incidence of plume moth and were on par with each other at 14 DAS.

At third spray

There was overall decline in population of plume moth after third spray. There was no plume moth incidence observed in the treatments T₂ to T₈. Significantly higher population of 2.17, 2.00 and 1.07 larvae per plant was noticed in the treatment T₉ at third, seventh and 14 DAS, respectively (Table 25).

4.4.1.3.2 Second year (2012-13)

At first spray

At seventh DAS, the treatments T₉ and T₁ registered 0.93 and 0.87 larvae per plant, respectively and were statistically on par with each other, whereas, there was no incidence of plume moth recorded in the remaining treatments (Table 26).

Further there was no incidence of plume moth recorded in treatments T₂, T₆ and T₈ at 14 DAS. Higher incidence of 1.17 larvae per plant was recorded in the treatment T₁, however, it was statistically on par with T₉ (1.07 larvae/plant)

At second spray

At third DAS, least incidence of plume moth was observed in T₃ (0.20 larvae/plant) and T₅ (0.23 larvae/plant), which were statistically on par with each other. However on the contrary, significantly higher incidence (2.20 larvae/plant) was noticed in treatment T₉ (Table 26). Similar trend was observed at seventh and 14 DAS with respect to the plume moth incidence. The treatments T₃ (0.27 and 0.40 larvae/plant) and T₅ (0.36 and 0.58 larvae/plant) recorded least incidence of plume moth at seventh and 14 DAS. Significantly higher incidence of 2.30 and 2.80 larvae per plant was observed at seventh and 14 DAS, respectively.

At third spray

There was gradual decline in the incidence of plume moth after third spray. However, there was no incidence found in the treatments T₂ to T₈. Significantly higher population of 3.27, 2.73 and 1.17 larvae per plant was noticed in the treatment T₉ at third, seventh and 14 DAS, respectively (Table 26).

4.4.2 Effect of various treatments on pod damage and grain yield of pigeonpea

4.4.2.1 Pod damage

The data on effect of various treatments on per cent pod damage by gram pod borer, plume moth and pod fly was recorded at harvest and presented in table 27.

4.4.2.1.1 Gram pod borer

The gram pod borer inflicted least pod damage of 11.60 per cent in the treatment T₄, which was statistically on par with T₂ (12.50%) during first year. Significantly higher pod damage of 44.67 per cent was noticed in the treatment T₉ and was statistically on par with T₁ (43.67%) (Table 27). During the second year, the treatment T₄ registered least pod damage of 10.83 per cent followed by T₂ (11.67%). Significantly higher pod damage (42.63%) was recorded in the treatment T₉, which was statistically on par with T₁ (41.57%).

Pooled analysis also indicated the similar trend and pod damage by gram pod borer was ranged from 11.22 (T₄) to 43.65 per cent (T₉).

4.4.2.1.2 Plume moth

During the first year, significantly lower pod damage of 5.40 per cent by plume moth was recorded by treatment T₃, which was followed by T₅ (6.33%) (Table 27). During the second year, least pod damage was registered in treatments T₃ (5.60%) and T₅ (5.80%), which were statistically on par with each other. Significantly higher pod damage of 18.57 and 17.73 per cent was recorded by the treatment T₉ during first and second year of study and was statistically on par with treatment T₁ (19.67 and 17.67%), respectively.
Table 27: Impact of different treatments on the pod damage and grain yield of pigeonpea during 2011-12 and 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>Per cent pod damage*</th>
<th>Grain yield (Kg/ha)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GPB</td>
<td>Plume moth</td>
</tr>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of caterpillars</td>
<td>43.67  (41.36)</td>
<td>41.57 (40.14)</td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>12.50 (20.70)</td>
<td>11.67 (19.97)</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbicidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>16.73 (24.17)</td>
<td>15.60 (23.26)</td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>11.60 (19.91)</td>
<td>10.83 (19.22)</td>
</tr>
<tr>
<td>T5</td>
<td>Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>24.52 (29.68)</td>
<td>22.70 (28.45)</td>
</tr>
<tr>
<td>T6</td>
<td>DDVP 76 EC (0.5 ml/l) - Bacillus thuringiensis (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
<td>13.35 (21.43)</td>
<td>14.27 (22.19)</td>
</tr>
<tr>
<td>T7</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>26.22 (30.80)</td>
<td>25.60 (30.39)</td>
</tr>
<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>21.82 (27.84)</td>
<td>19.87 (26.47)</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>44.67 (41.94)</td>
<td>42.63 (40.76)</td>
</tr>
<tr>
<td></td>
<td>SEm±</td>
<td>0.34</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>CD (0.05)</td>
<td>1.01</td>
<td>0.64</td>
</tr>
</tbody>
</table>

*Mean of three replications.
Values in parentheses are arc sine transformations.
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
GPB: Gram pod borer.
Similar trend was observed in pooled data and pod damage by plume moth was ranged from 5.50 per cent in the treatment $T_3$ to 18.67 per cent in $T_1$.

### 4.4.2.1.3 Pod fly

During the first year, significantly least pod damage of 4.38 per cent was noticed in treatment $T_5$, which was followed by $T_3$ (5.83%). The higher pod damage was recorded by the treatment $T_1$ (11.25%) and $T_9$ (10.87%), which were statistically on par with each other (Table 27).

During the second year, lower pod damage of 5.23 per cent was observed in the treatment $T_8$, which was statistically on par with $T_3$ (5.70%). The higher pod damage of 13.20 per cent was noticed in the treatment $T_9$, which was statistically on par with $T_1$ (12.83%) treatment.

Pooled data indicated the lowest pod damage by pod fly in the treatment $T_5$ (4.81 %) and highest in $T_1$ (12.04 %).

### 4.4.2.2 Grain yield

The grain yield of pigeonpea as influenced by different insecticidal treatments is presented in Table 27.

Significantly higher grain yield of 1084 and 1165 kg per hectare was obtained by the treatment $T_4$ during first (2011-12) and second year (2012-13), respectively. The next best treatment was $T_2$ which recorded grain yield of 987 and 1100 kg per hectare during first and the second year, respectively. Significantly lower grain yield of 466 and 420 kg per hectare was recorded by the treatment $T_9$ during first and the second year (Table 27).

On the basis of pooled data the highest grain yield was obtained in the treatment $T_4$ (1125 kg/ha) and lowest in the treatment $T_9$ (443 kg/ha).

### 4.4.3 Cost effectiveness of various conventional insecticides employed in the management of major insect pests of pigeonpea during 2011-12 and 2012-13

The data on net returns and B:C ratio recorded by various treatments employed in carrying field experiment are presented in Table 28.

Among the various treatments, highest net return (Rs. 27150/ha) was obtained from treatment $T_4$ with highest B:C ratio of 2.52. Lowest net returns (Rs.1020/ha) and B:C ratio (1.06) was recorded by treatment $T_9$.

### 4.5 Efficacy of various biorational insecticides against major insect pests of pigeonpea

The data on efficacy of various treatments against major insect pests of pigeonpea during first (2011-12) and second year (2012-13) of study under field condition were recorded at a day before spray, three, seven and fourteen days after first, second and third spray.

#### 4.5.1 Effect of various treatments on pest incidence

##### 4.5.1.1 Spotted pod borer, *Maruca vitrata* (Geyer)

The results on efficacy of various biorational insecticides against spotted pod borer during first and second year of study have been presented in tables 29 and 30.

#### 4.5.1.1.1 First year (2011-12)

At first spray

A day before treatment application, the incidence of spotted pod borer did not differ significantly and the incidence varied between 2.82 and 3.27 webs per plant in various treatments (Table 29).

Significantly higher incidence was recorded by the treatment $T_9$ with 5.13, 7.07 and 8.93 webs per plant at third, seventh and 14 DAS, respectively, however the remaining treatments were at par with each other throughout the period of observation after the first spray.
Table 28: Cost effectiveness of various conventional insecticides in the management of major insect pests of pigeonpea during 2011-12 and 2012-13 (pooled)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>Mean yield (Kg/ha)</th>
<th>Cost of production (Rs/ha)</th>
<th>Cost of protection (Rs/ha)</th>
<th>Total cost (Rs/ha)</th>
<th>Gross return (Rs/ha)</th>
<th>Net return (Rs/ha)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Bird perches - Hand collection of Weevils/ caterpillars</td>
<td>638</td>
<td>16700</td>
<td>750</td>
<td>17450</td>
<td>25520</td>
<td>8070</td>
<td>1.46</td>
</tr>
<tr>
<td>T2</td>
<td>Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)</td>
<td>1043</td>
<td>16700</td>
<td>1540</td>
<td>18240</td>
<td>41733</td>
<td>23493</td>
<td>2.29</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)</td>
<td>944</td>
<td>16700</td>
<td>1676</td>
<td>18376</td>
<td>37753</td>
<td>19377</td>
<td>2.05</td>
</tr>
<tr>
<td>T4</td>
<td>Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)</td>
<td>1125</td>
<td>16700</td>
<td>1130</td>
<td>17830</td>
<td>44980</td>
<td>27150</td>
<td>2.52</td>
</tr>
<tr>
<td>T5</td>
<td>Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)</td>
<td>863</td>
<td>16700</td>
<td>1296</td>
<td>17996</td>
<td>34520</td>
<td>16524</td>
<td>1.92</td>
</tr>
<tr>
<td>T6</td>
<td>DDVP 76 EC (0.5 ml/l) - B.t. (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)</td>
<td>917</td>
<td>16700</td>
<td>6096</td>
<td>22796</td>
<td>36680</td>
<td>13884</td>
<td>1.61</td>
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<tr>
<td>T7</td>
<td>Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 ml/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>840</td>
<td>16700</td>
<td>3110</td>
<td>19810</td>
<td>33593</td>
<td>13783</td>
<td>1.70</td>
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<tr>
<td>T8</td>
<td>Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)</td>
<td>808</td>
<td>16700</td>
<td>1880</td>
<td>18580</td>
<td>32333</td>
<td>13753</td>
<td>1.74</td>
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<tr>
<td>T9</td>
<td>Untreated check</td>
<td>443</td>
<td>16700</td>
<td>0.00</td>
<td>16700</td>
<td>17720</td>
<td>1020</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Note: Sale price of pigeonpea: Rs. 4000 per quintal
Table 29: Efficacy of different treatments against spotted pod borer, *Maruca vitrata* (Geyer) in pigeonpea during 2011-12

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th><em>No. of webs/plant after</em></th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Nimbecidine 0.03 EC (3ml/l) - HaNPV (250 LE) - <em>Bacillus thuringiensis</em> (B.t.) (2 kg/ha)</td>
<td>3.27(1.94)a</td>
<td>1.75(1.50)a</td>
<td>3.08(1.89)a</td>
<td>5.02(2.35)a</td>
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<tr>
<td>T2</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Beauveria bassiana (2x10^8 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
<td>3.00(1.87)a</td>
<td>1.68(1.47)a</td>
<td>2.62(1.77)a</td>
<td>4.78(2.30)a</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Nomuraea rileyi (2x10^8 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
<td>2.82(1.82)a</td>
<td>1.53(1.42)a</td>
<td>2.86(1.83)a</td>
<td>5.18(2.36)a</td>
</tr>
<tr>
<td>T4</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Metarhizium anisopliae</em> (2x10^8 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
<td>3.15(1.91)a</td>
<td>1.43(1.39)a</td>
<td>3.17(1.91)a</td>
<td>4.86(2.31)a</td>
</tr>
<tr>
<td>T5</td>
<td>Nimbecidine 0.03 EC (3ml/l) - HaNPV (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>3.07(1.89)a</td>
<td>1.67(1.47)a</td>
<td>2.97(1.86)a</td>
<td>5.12(2.52)a</td>
</tr>
<tr>
<td>T6</td>
<td>Nimbecidine 0.03 EC (3ml/l) - B. bassiana (2x10^8 spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>2.97(1.86)a</td>
<td>1.71(1.49)a</td>
<td>2.76(1.80)a</td>
<td>5.17(2.38)a</td>
</tr>
<tr>
<td>T7</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>N. rileyi</em> (2x10^8 spores) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>3.12(1.90)a</td>
<td>1.44(1.39)a</td>
<td>2.84(1.85)a</td>
<td>4.70(2.28)a</td>
</tr>
<tr>
<td>T8</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. t.</em> (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>2.96(1.86)a</td>
<td>1.53(1.42)a</td>
<td>3.21(2.37)a</td>
<td>5.06(2.36)a</td>
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<tr>
<td>T9</td>
<td>Untreated check</td>
<td>3.17(1.91)a</td>
<td>5.13(2.37)b</td>
<td>7.07(2.75)b</td>
<td>8.93(3.07)b</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
**DBS:** Day before spraying, **DAS:** Days after spraying
Table 30: Efficacy of various treatments against spotted pod borer, *Maruca vitrata* (Geyer) in pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>DBS 3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
<th>II spray 3 DAS</th>
<th>7 DAS</th>
<th>14 DAS</th>
<th>III spray 3 DAS</th>
<th>7 DAS</th>
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*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

DBS: Day before spraying, DAS: Days after spraying
At second spray

At third DAS, lowest incidence of spotted pod borer was noticed in treatment T_6 (5.64 webs/plant), however it was statistically on par with the treatments T_1, T_2, T_3, T_4, T_5, T_7 and T_8. Significantly higher incidence was recorded by the treatment T_9 with 8.89 webs per plant (Table 29).

Similar trend was followed at seventh and 14 DAS with least incidence observed in the treatment T_2 with 6.16 and 5.12 webs per plant, respectively, which was on par with the treatments T_1, T_3, T_4, T_5, T_7 and T_8. Significantly higher incidence of 8.04 and 7.54 webs per plant was observed in the treatment T_9 at seventh and 14 DAS, respectively.

At third spray

There was overall decline in the incidence of spotted pod borer after third spray (Table 29). There was no incidence of spotted pod borer in treatments T_5, T_6, T_7 and T_8 at third and seventh DAS, whereas significantly higher incidence was noticed in the treatment T_9 with 5.15 and 2.24 webs per plant at third and seventh DAS, respectively.

4.5.1.1.2 Second year (2012-13)

At first spray

A day prior to the imposition of treatments the incidence of spotted pod borer among various treatments was statistically non significant and ranged between 3.18 and 4.14 webs per plant among the treatments (Table 30).

Significantly higher incidence of spotted pod borer was recorded in the treatment T_9 with 6.56, 6.82 and 9.66 webs per plant at third, seventh and 14 DAS, respectively. The remaining treatments were statistically on par with each other throughout the period of observation after the first spray.

At second spray

At third DAS, least incidence was noticed in treatment T_2 with 4.77 webs per plant, which was on par with the treatments T_1, T_3, T_4, T_5, T_6, T_7 and T_8. Significantly higher incidence of spotted pod borer was observed in the treatment T_9 with 8.23 webs per plant (Table 30).

Similar trend was noticed at seventh and 14 DAS and significantly higher incidence was noticed in the treatment T_9 with 7.77 and 5.63 webs per plant at seventh and 14 DAS, respectively, whereas rest of the treatments were found at par with each other.

At third spray

There was gradual decline in the incidence of spotted pod borer after third spray. There was no incidence observed in the treatments, T_5 to T_8. Significantly higher incidence was noticed in the treatment T_9 with 3.81 and 1.07 webs per plant at third and seventh DAS, respectively (Table 30).

4.5.1.2 Gram pod borer, *Helicoverpa armigera* (Hubner)

The results on efficacy of various biorational insecticides against gram pod borer during first and second year of study have been presented in tables 31 and 32.

4.5.1.2.1 First year (2011-12)

At first spray

The population of gram pod borer a day prior to first spray ranged from 1.76 to 2.12 larvae per plant and were at par with each other (Table 31).

Significantly higher population was observed in the treatment T_9 with 3.14 larvae per plant at third DAS. However, rest of the treatments were found on par with each other throughout the period of observation at first spray.

At second spray

At third DAS, significantly lower larval count was registered by the treatment T_8 with 0.67 larvae per plant and was found superior over rest of the treatments, whereas the treatment T_9 recorded higher population (4.95 larvae/plant) of gram pod borer during the period (Table 31).
Table 31: Efficacy of various treatments against gram pod borer, *Helicoverpa armigera* (Hubner) on pigeonpea during 2011-12

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBS 3 DAS 7 DAS 14 DAS 3 DAS 7 DAS 14 DAS 3 DAS 7 DAS 14 DAS 3 DAS 7 DAS 14 DAS 3 DAS 7 DAS 14 DAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>HaNPV</em> (250 LE) - <em>Bacillus thuringiensis</em> (B.t.) (2 kg/ha)</td>
<td>1.96 (1.57)</td>
<td>1.34 (1.35)</td>
<td>1.76 (1.50)</td>
</tr>
<tr>
<td>T2</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Beauveria bassiana</em> (2x10⁸ spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>1.76 (1.50)</td>
<td>1.06 (1.25)</td>
<td>2.05 (1.59)</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Nomuraea rileyi</em> (2 x10⁸ spores/g) (2g/l) – B.t. (2 kg/ha)</td>
<td>1.87 (1.54)</td>
<td>1.13 (1.27)</td>
<td>1.92 (1.56)</td>
</tr>
<tr>
<td>T4</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Metarhizium anisopliae</em> (2 x10⁸ spores/g) (2g/l) – B.t. (2 kg/ha)</td>
<td>1.96 (1.57)</td>
<td>1.21 (1.31)</td>
<td>1.63 (1.46)</td>
</tr>
<tr>
<td>T5</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>HaNPV</em> (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>2.10 (1.61)</td>
<td>1.26 (1.33)</td>
<td>2.03 (1.55)</td>
</tr>
<tr>
<td>T6</td>
<td>Nimbecidine 0.03 EC (3ml/l) – <em>B. bassiana</em> (2x10⁸ spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>1.99 (1.58)</td>
<td>1.08 (1.25)</td>
<td>1.90 (1.55)</td>
</tr>
<tr>
<td>T7</td>
<td>Nimbecidine 0.03 EC (3ml/l) – <em>N. rileyi</em> (2 x10⁸ spores) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>2.12 (1.62)</td>
<td>1.18 (1.30)</td>
<td>1.96 (1.57)</td>
</tr>
<tr>
<td>T8</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. t. (2 kg/ha)</em> - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>1.96 (1.57)</td>
<td>1.13 (1.27)</td>
<td>2.07 (1.60)</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>2.03 (1.59)</td>
<td>3.14 (1.90)</td>
<td>3.93 (2.10)</td>
</tr>
<tr>
<td></td>
<td>SEM±</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>CD (0.05)</td>
<td>0.15</td>
<td>0.14</td>
<td>0.22</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

**DBS:** Day before spraying, **DAS:** Days after spraying
Table 32: Efficacy of various treatments against gram pod borer, *Helicoverpa armigera* (Hubner) in pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Treatments</th>
<th>*No. of larvae/plant after 7 DAS</th>
<th>*No. of larvae/plant after 14 DAS</th>
<th>*No. of larvae/plant after 3 DAS</th>
<th>*No. of larvae/plant after 14 DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sl. No</td>
<td>I spray</td>
<td>II spray</td>
<td>III spray</td>
<td>III spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DBS</td>
<td>3 DAS</td>
<td>7 DAS</td>
<td>14DAS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>HaNPV</em> (250 LE) - <em>Bacillus thuringiensis</em> (B.t.) (2 kg/ha)</td>
<td>1.63 (1.46)a</td>
<td>1.24 (1.31)a</td>
<td>1.85 (1.53)a</td>
<td>2.66 (1.78)a</td>
</tr>
<tr>
<td>T2</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Beauveria bassiana</em> (2x10⁶ spores/g) (2g/l) - B.t (2 kg/ha)</td>
<td>1.52 (1.42)a</td>
<td>1.10 (1.26)a</td>
<td>2.18 (1.63)a</td>
<td>2.55 (1.74)a</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Nomuraea rileyi</em> (2x10⁶ spores/g) (2g/l) - B.t (2 kg/ha)</td>
<td>1.77 (1.50)a</td>
<td>1.21 (1.31)a</td>
<td>1.92 (1.55)a</td>
<td>2.92 (1.84)a</td>
</tr>
<tr>
<td>T4</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Metarhizium anisopliae</em> (2x10⁶ spores/g) (2g/l) - B.t (2 kg/ha)</td>
<td>1.51 (1.41)a</td>
<td>1.17 (1.29)a</td>
<td>2.17 (1.63)a</td>
<td>2.78 (1.81)a</td>
</tr>
<tr>
<td>T5</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>HaNPV</em> (250 LE/ha) - Flubendiamide 480 SC (0.1 m/l)</td>
<td>1.80 (1.51)a</td>
<td>1.26 (1.32)a</td>
<td>1.93 (1.56)a</td>
<td>3.02 (1.87)a</td>
</tr>
<tr>
<td>T6</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. bassiana</em> (2x10⁶ spores/g) (2g/l) - Flubendiamide 480 SC (0.1 m/l)</td>
<td>1.58 (1.44)a</td>
<td>1.13 (1.27)a</td>
<td>2.11 (1.61)a</td>
<td>2.90 (1.84)a</td>
</tr>
<tr>
<td>T7</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>N. rileyi</em> (2x10⁶ spores) (2g/l) - Flubendiamide 480 SC (0.1 m/l)</td>
<td>1.81 (1.51)a</td>
<td>1.17 (1.29)a</td>
<td>2.07 (1.60)a</td>
<td>2.95 (1.85)a</td>
</tr>
<tr>
<td>T8</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. thuringiensis</em> (B.t) (2 kg/ha) - Flubendiamide 480 SC (0.1 m/l)</td>
<td>1.91 (1.55)a</td>
<td>1.25 (1.31)a</td>
<td>1.96 (1.56)a</td>
<td>2.89 (1.84)a</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>1.96 (1.56)a</td>
<td>2.77 (1.81)b</td>
<td>3.64 (2.03)b</td>
<td>4.51 (2.24)b</td>
</tr>
<tr>
<td></td>
<td>SEm±</td>
<td>0.09</td>
<td>0.07</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>CD (0.05)</td>
<td>NS</td>
<td>0.22</td>
<td>0.22</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Mean of three replications
Values in parentheses are square root transformations
In a column, means followed by same letter are not significantly different at P = 0.05 as per DMRT.
**DBS**: Day before spraying, **DAS**: Days after spraying
At seventh DAS, the treatment $T_5$ proved its superiority by recording 0.64 larvae per plant, however it was on par with treatments $T_1$ (0.72 larvae/plant) and $T_6$ (0.88 larvae/plant).

The treatments $T_1$ and $T_5$ registered lowest population of 0.56 and 0.32 larvae per plant, respectively at 14 DAS which were on par with each other. Significantly higher population of 6.55 larvae per plant was recorded in $T_9$.

At third spray

After third spray, the treatments $T_5$ to $T_8$ were found superior in reducing the larval population over rest of the treatments. Significantly higher population of 6.96, 7.80 and 3.47 larvae per plant was observed in the treatments $T_9$ at third, seventh and 14 days after third spray, respectively (Table 31).

4.5.1.2.2 Second year (2012-13)

At first spray

The pre-treatment observation indicated non-significant difference on larval population among the treatments and was ranged from 1.51 to 1.96 larvae per plant (Table 32).

At third DAS, the treatments $T_1$ to $T_8$ reduced the larval population significantly and found superior over untreated check ($T_9$) which recorded 2.77 larvae per plant.

Similar trend was followed at seventh and 14 DAS and all the treatments tested were statistically superior over untreated check. Significantly higher population of 3.64 and 4.51 larvae per plant was observed on seventh and 14 days after first spray, respectively.

At second spray

The treatment $T_8$ proved to be superior over rest of the treatments by recording 0.81 larvae per plant at third DAS and significantly higher population was observed in the treatment $T_9$ with 4.85 larvae per plant (Table 32).

At seventh DAS, the treatments $T_1$ and $T_5$ recorded least population of 0.25 and 0.32 larvae per plant, respectively, which were statistically on par with each other. This was followed by the treatment $T_8$ by recording 0.95 larvae per plant. Significantly higher population was observed in the treatment $T_9$ with 5.17 larvae per plant.

The larval count at 14 DAS followed the same trend as that of at seventh DAS. The treatments $T_1$ and $T_5$ recorded least larval count (0.26 and 0.27 larvae/plant), whereas $T_9$ registered significantly higher population of 6.04 larvae per plant.

At third spray

After third spray, the treatments $T_5$ to $T_8$ found superior over rest of the treatments in reducing the larval population. Significantly higher population of 7.03, 7.32 and 4.18 larvae per plant were observed at third, seventh and 14 days after third spray, respectively (Table 32).

4.5.1.3 Plume moth, *Exelastis atomosa* (May.)

The results on the efficacy of biorational insecticides against plume moth during first and second year of study have been presented in tables 33 and 34.

4.5.1.3.1 First year (2011-12)

At first spray

At seventh DAS, the treatment $T_9$ only recorded 0.67 larvae per plant and further there was no incidence of plume moth was seen in remaining treatments (Table 33).

At 14 DAS, the treatments $T_1$ to $T_8$ were statistically on par with each other and were found to be superior in reducing the plume moth incidence over untreated check. Significantly higher incidence (0.94 larvae/plant) was recorded in treatment $T_9$.

At second spray

The treatment $T_2$ recorded the lower population (0.26 larvae/plant) of plume moth at third DAS and was on par with the treatments $T_3$, $T_4$, $T_5$, $T_6$ and $T_7$. Significantly higher population was recorded by the treatment $T_9$ with 1.27 larvae per plant (Table 33).
Table 33: Efficacy of various treatments against plume moth, *Exelastis atomosa* (May.) in pigeonpea during 2011-12

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th><em>No. of larvae/plant after</em></th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DBS 3 DAS 7 DAS 14 DAS</td>
<td></td>
<td>3 DAS 7 DAS 14 DAS</td>
<td></td>
</tr>
<tr>
<td>T₁</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Ha</em>NPV (250 LE) - <em>Bacillus thuringiensis</em> (B.t.) (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.28 (0.88)</td>
<td>0.66 (1.08)</td>
</tr>
<tr>
<td>T₂</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Beauveria bassiana</em> (2x10⁸ spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.32 (0.91)</td>
<td>0.26 (0.87)</td>
</tr>
<tr>
<td>T₃</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Nomuraea rileyi</em> (2x10⁸ spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.26 (0.87)</td>
<td>0.37 (0.93)</td>
</tr>
<tr>
<td>T₄</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Metarhizium anisopliae</em> (2x10⁸ spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.29 (0.89)</td>
<td>0.36 (0.92)</td>
</tr>
<tr>
<td>T₅</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Ha</em>NPV (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.26 (0.87)</td>
<td>0.35 (0.92)</td>
</tr>
<tr>
<td>T₆</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. bassiana</em> (2x10⁸ spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.31 (0.90)</td>
<td>0.30 (0.89)</td>
</tr>
<tr>
<td>T₇</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>N. rileyi</em> (2x10⁸ spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.25 (0.87)</td>
<td>0.41 (0.96)</td>
</tr>
<tr>
<td>T₈</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. t.</em> (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.30 (0.90)</td>
<td>0.64 (1.06)</td>
</tr>
<tr>
<td>T₉</td>
<td>Untreated check</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.67 (1.07)</td>
<td>0.94 (1.20)</td>
</tr>
</tbody>
</table>

**SEm±** | - | - | 0.03 | 0.01 | 0.03 | 0.04 | 0.03 | 0.05 | 0.03 | 0.01
**CD (0.05)** | - | - | 0.08 | 0.03 | 0.08 | 0.11 | 0.09 | 0.15 | 0.10 | 0.04

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

**DBS**: Day before spraying, **DAS**: Days after spraying
Table 34: Efficacy of various treatments against plume moth, *Exelastis atomosa* (May.) in pigeonpea during 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>I spray</th>
<th>II spray</th>
<th>III spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DBS</td>
<td>3 DAS</td>
<td>7 DAS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. of larva/plant after</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>HaNPV</em> (250 LE) - <em>Bacillus thuringiensis</em> (B.t.) (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.25 (0.86)</td>
</tr>
<tr>
<td>T2</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Beauveria bassiana</em> (2x10^9 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.27 (0.88)</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Nomuraea rileyi</em> (2x10^8 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.32 (0.91)</td>
</tr>
<tr>
<td>T4</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>Metarhizium anisopliae</em> (2x10^8 spores/g) (2g/l) - <em>B.t.</em> (2 kg/ha)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.26 (0.87)</td>
</tr>
<tr>
<td>T5</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>HaNPV</em> (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.31 (0.90)</td>
</tr>
<tr>
<td>T6</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. bassiana</em> (2x10^9 spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.25 (0.86)</td>
</tr>
<tr>
<td>T7</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>N. rileyi</em> (2x10^8 spores) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.26 (0.87)</td>
</tr>
<tr>
<td>T8</td>
<td>Nimbecidine 0.03 EC (3ml/l) - <em>B. t.</em> (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.29 (0.89)</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
<td>0.63 (1.06)</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are square root transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.

**DBS**: Day before spraying, **DAS**: Days after spraying
At seventh DAS, the treatment T_2 recorded lower incidence of plume moth (0.74 larvae/plant) and was on par with treatments T_1, T_3, T_5, T_6, T_7 and T_8. Significantly higher population of 1.89 larvae per plant was recorded in treatment T_9.

Significantly higher incidence of 2.80 larvae per plant was recorded by untreated check (T_9) at 14 DAS, whereas rest of the treatments were found superior in reducing the larval population over the treatment T_9.

At third spray

After third spray, the treatments T_5 to T_8 were found superior over rest of the treatments in reducing the larval population and statistically on par with each other. Significantly higher population of 1.68, 1.46 and 0.98 larvae per plant was observed at third, seventh and 14 days after third spray, respectively in the treatment T_9 (Table 33).

4.5.1.3.2 Second year (2011-12)

At first spray

At 14 days after first spray, the treatment T_9 recorded significantly higher incidence of plume moth with 0.63 larvae per plant, while rest of the treatments were statistically on par with each other and were superior over the treatment T_9 (Table 34).

At second spray

At third DAS, least population of 0.36 larvae per plant recorded by the treatment T_6, which was statistically on par with the treatments T_1, T_3, T_4, T_7 and T_8. Significantly higher incidence was noticed in the treatment T_9 with 1.57 larvae per plant (Table 34).

Significantly higher incidence of 2.09 larvae per plant was recorded by the treatment T_9 at seventh DAS. However, the remaining treatments were statistically on par with each other and proved its superiority over the treatment T_9.

At 14 DAS, the treatment T_6 registered least incidence with 1.45 larvae per plant, which was statistically on par with the treatments T_2, T_3, T_4, T_7, and T_8. Significantly higher incidence of 2.69 larvae per plant recorded by the treatment T_9.

At third spray

After the third spray, the treatments T_5 to T_8 proved their superiority over rest of the treatments by reducing the larval population. Significantly higher population of 2.58, 1.06 and 0.87 larvae per plant were observed at third, seventh and 14 days after third spray, respectively in the treatment T_9 (Table 34).

4.5.2 Effect of various treatments on pod damage and grain yield of pigeonpea

4.5.2.1 Pod damage

The data on impact of various biorational insecticides on pod damage by gram pod borer, plume moth and pod fly was recorded at harvest and presented in table 35.

4.5.2.1.1 Gram pod borer

During the first year (2011-12) of study, the treatment T_5 found superior by reducing per cent pod damage (21.33%) by gram pod borer, which was statistically on par with T_8 (23.47%). Significantly higher pod damage of 47.83 per cent was recorded in the treatment T_9 (Table 35).

Similar trend was followed during second year (2012-13) of study and least pod damage was recorded by the treatment T_5 (19.52%) and T_8 (22.81%), which were statistically on par with each other. Significantly higher pod damage of 43.89 per cent recorded with the treatment T_9.

On the basis of two year pooled data the pod damage by gram pod borer was ranged between 20.43 per cent in the treatment T_5 and 45.86 per cent in T_9.

4.5.2.1.2 Plume moth

The plume moth caused least pod damage of 9.59 per cent in the treatment T_6 during the first year, which was statistically on par with the treatments T_5 (10.41%), T_7 (10.47%) and T_8 (9.67%). Significantly higher pod damage of 17.88 per cent was noticed in the treatment T_9 (Table 35).
Table 35: Efficacy of different treatments on the pod damage and grain yield of pigeonpea during 2011-12 and 2012-13

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>Per cent pod damage*</th>
<th>Grain yield (Kg/ha)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GPB</td>
<td>Plume moth</td>
<td>Pod fly</td>
</tr>
<tr>
<td>T1</td>
<td>Nimbecidine 0.03 EC (3ml/l) - B.t. (2 kg/ha)</td>
<td>33.74</td>
<td>31.93</td>
<td>32.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(35.51)†</td>
<td>(34.40)‡</td>
<td>(34.96)‡</td>
</tr>
<tr>
<td>T2</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Beauveria bassiana (2 x 10^3 spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>37.50</td>
<td>32.19</td>
<td>34.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(37.76)cd</td>
<td>(34.56)cd</td>
<td>(36.17)cd</td>
</tr>
<tr>
<td>T3</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Nomuraea rileyi (2 x 10^3 spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>38.96</td>
<td>30.48</td>
<td>34.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(38.59)cd</td>
<td>(33.49)cd</td>
<td>(36.10)cd</td>
</tr>
<tr>
<td>T4</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Metarhizium anisopliae (2 x 10^3 spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>37.70</td>
<td>33.21</td>
<td>35.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(37.87)cd</td>
<td>(35.19)d</td>
<td>(36.54)d</td>
</tr>
<tr>
<td>T5</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Flubendiamide 480 SC (0.1 ml/l) - B.t. (2 kg/ha)</td>
<td>21.33</td>
<td>19.52</td>
<td>20.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(27.51)†</td>
<td>(26.21)b</td>
<td>(26.87)a</td>
</tr>
<tr>
<td>T6</td>
<td>Nimbecidine 0.03 EC (3ml/l) - B. bassiana (2 x 10^3 spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>29.06</td>
<td>27.93</td>
<td>28.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(32.60)†</td>
<td>(31.90)bc</td>
<td>(32.25)bc</td>
</tr>
<tr>
<td>T7</td>
<td>Nimbecidine 0.03 EC (3ml/l) - N. rileyi (2 x 10^3 spores) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>28.00</td>
<td>27.51</td>
<td>27.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(31.94)†</td>
<td>(31.60)b</td>
<td>(31.78)c</td>
</tr>
<tr>
<td>T8</td>
<td>Nimbecidine 0.03 EC (3ml/l) - B. t. (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>23.47</td>
<td>22.81</td>
<td>23.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(28.97)†</td>
<td>(28.52)a</td>
<td>(28.75)b</td>
</tr>
<tr>
<td>T9</td>
<td>Untreated check</td>
<td>47.83</td>
<td>43.89</td>
<td>45.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(43.76)a</td>
<td>(41.48)b</td>
<td>(42.62)b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SE±0.90</td>
<td>2.70</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Mean of three replications
Values in parentheses are arc sine transformations
In a column means followed by same letter are not significantly different at P = 0.05 as per DMRT.
GPB: Gram pod borer
Similar trend was followed during the second year of study and the treatments $T_5$ (8.51%), $T_6$ (7.51%), $T_7$ (7.62%) and $T_8$ (8.63%) performed as superior over rest of the treatments and were statistically on par with each other. However, the treatment $T_9$ registered significantly higher incidence of 16.26 per cent.

Pooled data indicated the lowest (8.55 %) pod damage by plume moth in the treatment $T_6$ and highest (17.07 %) in $T_9$.

4.5.2.1.3 Pod fly

The pod fly inflicted minimum pod damage of 6.78 per cent in the treatment $T_6$ during the first year, which was statistically on par with $T_5$ (6.92 %), $T_7$ (7.10 %) and $T_8$ (6.88 %). Significantly higher pod damage of 12.58 per cent was recorded by the treatment $T_9$ (Table 35).

Same trend was noticed during the second year also wherein the treatments $T_5$ (6.72%), $T_6$ (6.67%), $T_7$ (7.03%) and $T_8$ (6.81%) found superior over rest of the treatments in reducing the per cent pod damage, which were on par with each other, however higher per cent pod damage (13.18%) was observed in the treatment $T_9$.

The pooled analysis indicated the similar trend with respect to pod damage by pod fly and pod damage was ranged between 6.78 per cent ($T_6$) and 12.88 per cent ($T_9$).

4.5.2.2 Grain yield

The grain yield of pigeonpea as influenced by different treatments is presented in table 35.

Significantly higher grain yield of 887 kg per hectare was obtained in treatment $T_5$ during the first year, which was statistically on par with $T_8$ (884 kg/ha). This was followed by $T_6$ (770 kg/ha) and $T_7$ (783 kg/ha) treatments. Similar trend was noticed during second year of study and higher grain yield of 890 and 872 kg per hectare was obtained in the treatments $T_5$ and $T_8$, respectively.

On the basis of two year pooled data the highest grain yield of 888 kg per hectare was obtained in the treatment $T_5$ and lowest (452 kg/ha) in $T_9$.

4.5.3 Cost effectiveness of various biorational insecticides employed in the management of major insect pests of pigeonpea during 2011-12 and 2012-13

The data on net returns and B:C ratio recorded from various treatments employed in field experiment are presented in table 36.

Among the various treatments, highest net return of Rs. 16743 per hectare was obtained from the treatment $T_5$ with highest B:C ratio of 1.89. Whereas the lowest net returns of Rs.1380 per hectare and B:C ratio of 1.08 was recorded with treatment $T_9$. 
Table 36: Cost effectiveness of various biorational insecticides in the management of major insect pests of pigeonpea during 2011-12 and 2012-13 (pooled)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>Mean Yield (Kg/ha)</th>
<th>Cost of production (Rs/ha)</th>
<th>Cost of protection (Rs/ha)</th>
<th>Total cost (Rs/ha)</th>
<th>Gross return (Rs/ha)</th>
<th>Net return (Rs/ha)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Ha-NPV (250 LE) - Bacillus thuringiensis (2 kg/ha)</td>
<td>626</td>
<td>16700</td>
<td>4250</td>
<td>20950</td>
<td>25040</td>
<td>4090</td>
<td>1.20</td>
</tr>
<tr>
<td>T₂</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Beauveria bassiana (2x10⁸ spores/g) (2g/l) - B.t (2 kg/ha)</td>
<td>622</td>
<td>16700</td>
<td>4450</td>
<td>21150</td>
<td>24873</td>
<td>3723</td>
<td>1.18</td>
</tr>
<tr>
<td>T₃</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Nomuraea rileyi (2 x10⁸ spores/g) (2g/l) – B.t. (2 kg/ha)</td>
<td>600</td>
<td>16700</td>
<td>4450</td>
<td>21150</td>
<td>23993</td>
<td>2843</td>
<td>1.13</td>
</tr>
<tr>
<td>T₄</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Metarhizium anisopliae (2 x10⁸ spores/g) (2g/l) - B.t. (2 kg/ha)</td>
<td>615</td>
<td>16700</td>
<td>4450</td>
<td>21150</td>
<td>24607</td>
<td>3457</td>
<td>1.16</td>
</tr>
<tr>
<td>T₅</td>
<td>Nimbecidine 0.03 EC (3ml/l) - Ha NPV (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>888</td>
<td>16700</td>
<td>2090</td>
<td>18790</td>
<td>35533</td>
<td>16743</td>
<td>1.89</td>
</tr>
<tr>
<td>T₆</td>
<td>Nimbecidine 0.03 EC (3ml/l) - B. bassiana (2g/l)- Flubendiamide 480 SC (0.1 ml/l)</td>
<td>776</td>
<td>16700</td>
<td>2290</td>
<td>18990</td>
<td>31033</td>
<td>12043</td>
<td>1.63</td>
</tr>
<tr>
<td>T₇</td>
<td>Nimbecidine 0.03 EC (3ml/l) – N. rileyi (2g/l) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>793</td>
<td>16700</td>
<td>2290</td>
<td>18990</td>
<td>31700</td>
<td>12710</td>
<td>1.67</td>
</tr>
<tr>
<td>T₈</td>
<td>Nimbecidine 0.03 EC (3ml/l) - B. t. (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)</td>
<td>878</td>
<td>16700</td>
<td>2290</td>
<td>18990</td>
<td>35113</td>
<td>16123</td>
<td>1.85</td>
</tr>
<tr>
<td>T₉</td>
<td>Untreated check</td>
<td>452</td>
<td>16700</td>
<td>0.00</td>
<td>16700</td>
<td>18080</td>
<td>1380</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Note: Sale price of pigeonpea: Rs. 4000 per quintal
DISCUSSION

Among the pulses, the pigeonpea is the most important dietary component of human beings. India is the largest producer, contributing more than 90 per cent of the world’s production of pigeonpea. The major constraints that limit the realization of potential yield of pigeonpea include biotic and abiotic stresses prevalent across the pulse growing areas.

Among the biotic stresses, the crop is highly sensitive to attack by a wide range of insect pests both in the field (at various stages of crop growth) and storage. Majority of insect pests infest the crop at reproductive stage causing direct losses. Lepidopteran, hemipteran, dipteran and coleopteran group of insects are major yield reducing factors. These insect species belong to different categories, i.e., oligophagous to polyphagous, surface feeding to concealed feeding and chewing to piercing and sucking types. It has been proved beyond doubt that pest management can contribute upto 50 per cent increase in grain yield of pigeonpea (Sharma et al., 2010).

Studies were undertaken to evolve an effective and economic management strategy against major insect pests of pigeonpea and to establish the pest scenario in the northern transitional region of Karnataka. Efforts were also made to know the tolerance level of important cultivars of pigeonpea, which ultimately helps to develop effective IPM strategy.

The results obtained during the course of investigation are discussed in the light of available literature.

5.1 Survey of major insect pests of pigeonpea in the selected districts of northern transitional belt of Karnataka

Survey carried out in Belgaum, Dharwad and Haveri districts indicated varied level of pest incidence and were found feeding on pigeonpea at different stages of crop growth as revealed from two years survey data.

The insect pests viz., ash weevil (*Myllocerus discolor* F.), leaf webber (*Grapholita critica* Meyr.), hairy caterpillars (*Amsacta* spp.) and aphids (*Aphis craccivora* Koch) were noticed during the pre-flowering (vegetative) stage of the crop at first survey.

The results of second survey carried out during flowering stage of the crop recorded the activity of bud weevil (*Ceuthorhynchus asperulus* (Faust)), spotted pod borer (*Maruca vitrata* (Geyer)), hairy caterpillars (*Amsacta* spp.) and gram pod borer (*Helicoverpa armigera* Hubner).

The third survey conducted at pod formation stage revealed the presence of bud weevil, pod bugs (*Riptortus pedestris* (F.), *Anoplocnemis phasiana* (Fabricius) and *Clavigralla gibbosa* Spinola), gram pod borer (*H. armigera*), blister beetle (*Mylabris pustulata* (Thunberg)) and plume moth (*Exelastis atomosa* (May.)).

In general, the pest incidence on pigeonpea was higher in Haveri district followed by Dharwad district, which may be due to extensive cultivation of pigeonpea as an intercrop or sole crop. Comparatively the pest incidence was lesser in Belgaum district, where pigeonpea was grown marginally in isolated areas or around the high valued crops.

5.2 Seasonal abundance of major insect pests of pigeonpea in northern transitional belt of Karnataka

5.2.1 Seasonal incidence of insect pests

Studies on seasonal incidence conducted at MARS, Dharwad revealed the occurrence of hairy caterpillar (*Amsacta* spp.), leaf webber (*G. critica*), spotted pod borer (*M. vitrata*), gram pod borer (*H. armigera*), bud weevil (*C. asperulus*), blister beetle (*M. pustulata*), pod bugs (*C. gibbosa, A. phasiana* and *R. pedestris*) and plume moth (*E. atomosa*) at specific part of the year and stages of the crop growth (Fig. 1 and 2).

The hairy caterpillars and leaf webber were prevalent during vegetative stage of the crop. The incidence of hairy caterpillars was observed between 31st and 35th week (Meteorological Standard Week) during first year of observation with its peak during 34th week (August) and 33rd to 37th week during second year with a peak at 36th week (September), whereas the incidence of leaf webber was commenced on 32nd week and remained upto 37th week during first year and 35th to 40th week during...
Fig 1: Seasonal incidence of major insect pests of pigeonpea during 2011-12
Fig 2: Seasonal incidence of major insect pests of pigeonpea during 2012-13
second year. It reached its peak during 35th (August) and 37th week (September) during first and second year of study.

The insect pests prevalent during the flowering period of the crop were spotted pod borer, bud weevil and blister beetle. Spotted pod borer was observed from 44rd to 46th week during first year and 44th to 48th week during second year. The highest incidence was recorded during 45th (November) and 47th (November) week during first and second year. The incidence of bud weevil was noticed from 45th to 50th week and 44th to 50th week during first and second year. The peak population of bud weevil was recorded at 47th week (September) during both the years of study period. The peak activity of blister beetle was noticed at 45th (November) and 44th week (November) during first and second years of study.

The pod feeding insects viz., gram pod borer, pod bugs and plume moth were noticed and the incidence commenced at pod formation stage and extended till maturity of the crop. Gram pod borer was a major pest and found damaging the crop for longer duration than any other pest, whose presence was noticed at 43rd week and continued up to 51st week during both the years with its peak activity during 48th week (November). The presence of pod bugs was noticed from 43rd to 47th week during first year and 42nd to 47th week during second year. The peak activity of pod bugs was recorded at 44th week (November) for both the years of study. The incidence of plume moth was noticed at 47th week and remained up to 50th week which was associated with pod formation stage, whereas during second year it was observed from 46th to 50th week. The peak incidence of plume moth was noticed at 47th (November) and 48th week (November) during first and second year of study period.

The prevalence of aforesaid pests was, therefore, greatly influenced by crop stage and they had a definite temporal association with crop.

The present results are in conformity with the findings of Chaitanya et al. (2012) who noticed the infestation of \textit{M. vitrata} with the onset of flowering in the first week of November and remained up to crop maturity at Tirupati. Akhauri and Yadav (2002) reported maximum activity of \textit{M. vitrata} between second and last week of November at Dholi in Bihar. Concomitantly, Benagi et al. (2004) reported the activity of \textit{H. armigera} from 43rd week onwards coinciding with the pod formation stage at Gulbarga. However, Bajya et al. (2010) reported the availability of \textit{H. armigera} larvae from third week of August to first week of November with a peak during third week of September at Fatehabad in Haryana. According to Bhoyar et al. (2004) and Subharani and Singh (2009) the activity of plume moth was commenced during second and last week of November at Akola and Takyelpat (Imphal), respectively.

5.2.2 Influence of weather parameters on insect pests of pigeonpea

The incidence of pest was greatly influenced by the prevailing weather parameters like temperature, relative humidity and pattern as well as intensity of rainfall.

5.2.2.1 First year (2011-12)

The population of hairy caterpillar was much influenced by the weather parameters. The increased mean maximum temperature was not congenial for population buildup of hairy caterpillar, whereas increase in mean relative humidity favoured the pest buildup. The incidence of leaf webber had significant positive correlation with mean minimum temperature and mean relative humidity, whereas mean maximum temperature had significant negative impact on leaf webber incidence. The increase in mean relative humidity was found to be a limiting factor for the population buildup of spotted pod borer and blister beetle. Mean minimum temperature and mean rainfall had significant negative correlation with population build of gram pod borer, whereas mean maximum temperature showed significant positive correlation. The increase in mean minimum temperature and relative humidity significantly reduced the population of bud weevil. The weather factors such as mean minimum temperature, mean maximum temperature, mean relative humidity and mean rainfall did not influence on population buildup of pod bugs. Increase in mean minimum temperature was not congenial for the population buildup of plume moth.

5.2.2.2 Second year (2012-13)

The increase in mean minimum temperature favoured the incidence of hairy caterpillar and leaf webber, whereas increase in mean minimum temperature and mean relative humidity was not congenial for population buildup of spotted pod borer. Mean minimum temperature, mean relative
humidity and mean rainfall had significant negative relationship with gram pod borer, plume moth and bud weevil. The weather factors like mean minimum temperature, mean maximum temperature, relative humidity and rainfall had no significant influence on population buildup of pod bugs and blister beetle in pigeonpea ecosystem.

Similar observations were made by Bhoyar et al. (2004) who also reported the negative correlation between population of plume moth and minimum temperature. Concurrently, Patel and Koshiya (1999) observed that the population buildup of *H. armigera* had no correlation with physical factors.

The correlation between incidence of pest and weather factors during second year was not consistent with preceding year, however regression studies showed that all the weather factors under consideration had a significant role on population fluctuation of insect pests, therefore, it was difficult to establish the exact relationship between population buildup of pest and weather parameters.

Therefore, it can be inferred that the incidence of insect pests in pigeonpea was more closely associated with crop phenology rather than weather parameters.

5.2.3 Insect pest scenario of pigeonpea in transitional region of Karnataka

5.2.3.1 Insect pests

A total of 31 insect pests belonging to seven orders were reported during the course of investigation of which majority belonged to lepidoptera (42%) followed by hemiptera (26%), coleopteran (20%), diptera (3%), hymenoptera (3%), thysanoptera (3%) and orthoptera (3%) associated with pigeonpea ecosystem in the transitional zone of Karnataka (Fig. 3).

5.2.3.2 Natural enemies

The larval parasitoids *Campoletis chlorideae* Uchida, *Apanteles* sp., tachinid fly and egg parasitoid *Telenomus* sp. were recorded on *Helicoverpa armigera* (Hubner). The larval parasitoid *Apanteles taragamae* Viereck recorded on *Maruca vitrata* (Geyer) and *Glyptapanteles* sp. from hairy caterpillar (Arctiidae).

Similarly, Sujalata Devi et al. (2002) reported *C. chlorideae* Uchida, *Apanteles* sp., and Tachinid parasitoids from *H. armigera* in pigeonpea ecosystem. A potential larval parasitoid, *A. taragamae* Viereck on *M. vitrata* was reported by Dannon et al. (2012). The parasitisation of *H. armigera* eggs by *Telenomus* sp. was documented by Manjunath et al. (1970). Gupta et al. (2011) reported parasitoid, *Glyptapanteles* sp. from arctiidae.

The grubs of lady bird beetle, *Cheilomenes sexmaculata* (Fabricius) were found predating on aphids and leaf hoppers, whereas green lacewing, *Chrysoperla carnea* (Stephens) on aphids, thrips, leafhoppers and eggs of lepidoptera. The generalized predators like reduvid bug, dragonfly and spiders were also recorded from pigeonpea ecosystem. Similar findings were reported by Akhilesh Kumar and Nath (2003b) in pigeonpea ecosystem.

The dominant predatory birds were black drongo (*Dicrurus macrocercus* (Vieillot)), green bee eater (*Merops orientalis* (Latham)), mynah (*Acridotheres tristis* (Linnaeus)) and crow (*Corvus splendens* (Vieillot)). The similar reports were made by Sujalata Devi et al. (2002), Akhilesh Kumar and Nath (2003b) and Singh et al. (2011).

5.2.4 Effect of dates of sowing on the incidence of major insect pests of pigeonpea

The incidence of gall weevil started after 15 days of crop emergence and continued upto 45 days; however the incidence varied greatly among the different dates of sowing (Fig. 4). Early stage of the crop (15 to 45 days after crop emergence) having tender stem portion was found to be critical and vulnerable for attack by gall weevil. The early sown crop on first week of June suffered significantly lesser damage followed by third week of June and first week of July. The crop sown during third week of July and first week of August suffered to a greater extent damage and recorded as high as 90 per cent of the galled plants. The present study clearly reveals that the early sown crop escaped the pest incidence.

The crop sown during first and third week of June recorded least incidence of hairy caterpillar, leaf webber, spotted pod borer, gram pod borer, pod bugs and plume moth, which was followed by sowing on first week of July. The crop sown during third week of July and first week of August
Fig. 3. Proportion of different insect orders distributed on pigeonpea during the study period
Fig 4: The incidence of gall weevil (*Alcidodes collaris* Pascoe) in pigeonpea as influenced by different dates of sowing during 2011-12 and 2012-13.

Fig 4: The incidence of gall weevil (*Alcidodes collaris* Pascoe) in pigeonpea as influenced by dates of sowing during 2011-12 and 2012-13.
harboured higher population density of these pests. However the effect of dates of sowing on incidence of bud weevil and blister beetle was not greatly pronounced.

The present observations are in line with the findings of Gopali et al. (2010) who recorded the higher incidence of *M. vitrata* in late sown conditions and Kabaria et al. (1993) who advocated early sowing of pigeonpea during the first week of June to avoid pod borer, *M. vitrata* damage.

Thus, the present findings on alteration in date of sowing in minimizing the incidence of the pest in the pigeonpea categorically indicated that the early sowing of pigeonpea is a non cash input for achieving higher yield as well as reducing the pest load.

5.2.5 Effect of dates of sowing on pod damage by pigeonpea pod borers

The incidence of pod borers (gram pod borer, plume moth and pod fly) varied significantly among the different dates of sowing (Fig. 5).

The crop sown during first week of June sustained lesser pod damage by gram pod borer and plume moth, which was closely followed by third week of June and first week of July. Similarly, lower pod damage by pod fly was evident on crop sown during first week of June, which was followed by sowing during third week of June. In contrary, the late sown crop during third week of July and first week of August suffered to a higher extent of pod damage from all three pod borers. Thus, the damage by pod borers was low in early sown crop as it escaped the pest incidence and pod damage increased with advancement of date of sowing at fortnightly interval.

These results are in conformity with the findings of Nimse and Jat (2010) who reported that early sown (15th July) pigeonpea variety (ICPL-87) recorded lowest pod damage by *H. armigera* (3.13%), *E. atomosa* (6.56%) and *M. obtusa* (10.06%) as against the late sowing on 30th August (7.63, 29.88 and 20.15%, respectively). Similarly, Prasad et al. (1986) reported that pod damage due to pod borer complex was significantly lower (2.60%) when crop was sown on 10th July and highest (48.31%) in crop sown during 25th September.

The reduced pod borer (*H. armigera, E. atomosa* and *M. obtusa*) damage was reported by Gajendran et al. (2006) in early sown pigeonpea as compared to the farmers practice of late sowing (third week of July). The early-sown (first week of May) short-duration pigeonpea had less than 6.50 per cent pod damage by *H. armigera* whereas, pod damage to pigeonpea sown in mid-May (15-25th) and mid-June (15-25th) was 26.50 and 39.00 per cent, respectively (Dahiya et al., 1999).

5.2.6 Effect of dates of sowing on grain yield of pigeonpea

Significantly higher grain yield of pigeonpea was obtained from crop sown during third week of June, which was closely followed by sowing during first week of June. The grain yield was decreased with delay in sowing after third week of June (Fig. 6).

Early sown pigeonpea yielded better on account of lower pod borer damage coupled with lesser efforts as plant protection. Thus, this could be one of the important components of a pest management strategy in pigeonpea. The early sown crop of pigeonpea escaped from the incidence of various insect pests under study and recorded superior yield levels. The postponement of sowing of pigeonpea for various reasons will result in threefold yield reduction.

Similar result was recorded by Dahiya et al. (1999) who observed the decreased grain yield with a delay in sowing from 1.60 tonne per hectare with early sowing to 1.00 tonne per hectare with late sowing in mid-June.

5.3 Varietal screening to identify the tolerance level of important cultivars against major insect pests of pigeonpea

A total of ten cultivars (ICPL-87119, ICP-8863, BSMR-736, GC-11-39, TS-3(R), WRP-1, S-1, BRG-2, HY-3C and ICPH-2671) of pigeonpea were evaluated for tolerance/resistance to major insect pests under field condition.

5.3.1 Insect pest incidence

On the basis two year (2011-12 and 2012-13) mean data it was observed that, least incidence (2.88 webs/plant) of leaf webber was observed on BSMR-736, whereas significantly higher incidence (5.73 webs/plant) was found in ICPH-2671. The incidence of spotted pod borer was significantly lower (2.72 webs/plant) in ICP-8863 while higher incidence (9.83 webs/plant) was recorded in GC-11-39.
Fig 5 : Influence of dates of sowing on pod damage by different pod borers in pigeonpea (Pooled)

Fig 5: Influence of dates of sowing on pod damage by different pod borers in pigeonpea (Pooled)
Fig 6: Effect of dates of sowing on grain yield of pigeonpea during 2011-12 and 2012-13

**Fig 6 : Effect of dates of sowing on grain yield of pigeonpea during 2011-12 and 2012-13**
The incidence of gram pod borer was least (3.67 larvae/plant) in BSMR-736 and higher (6.77 larvae/plant) in ICPH-2671. The cultivar, GC-11-39 recorded least incidence of bud weevil (4.95 weevils/plant), whereas ICPH-2671 recorded higher incidence (9.71 weevils/plant). Similarly, GC-11-39 haboured lesser population (0.79 bugs/plant) of pod bugs as against against higher population density (2.12 bugs/plant) in BSMR-736. The cultivar, GC-11-39 recorded least incidence (0.63 larvae/plant) of plume moth and significantly higher incidence (3.13 larvae/plant) was noticed in S-1 (Fig. 7).

The incidence of spotted pod borer was high in early maturing variety (GC-11-39) having indeterminate growth habit, where flowers/pods were produced in bunches and least in medium maturing variety (ICP-8863). The incidence of leaf webber and gram pod borer was high in medium maturing hybrid (ICPH-2671) and least in long duration variety (BSMR-736). The incidence of bud weevil, pod bugs and plume moth was least in early maturing variety, GC-11-39. The higher incidence of pod bugs and plume moth was noticed in long duration varieties, BSMR-736 and S-1. The medium maturing hybrid, ICPH-2671 recorded higher incidence of bud weevil.

The flowering of early maturing variety coincided with peak activity of *M. vitrata*. The varieties with longer duration flowered during the declining phase of *M. vitrata* population resulted in relatively less damage. The management of *M. vitrata* using insecticides was delayed or even rendered ineffective because of webbings and concealed habitat of larvae, therefore, the choice of cultivars forms a vital component in managing the *M. vitrata* incidence.

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The present results are in conformity with the findings of Sharma and Franzmann (2000), Srinivasa Rao *et al.* (2006), Sunitha *et al.* (2008a) and Srivastava and Joshi (2011) who recorded the susceptibility of short duration varieties to *M. vitrata*. Similarly, Gopali *et al.* (2010) opined that the short duration variety, GC-11-39 with determinate growth habit was susceptible to *M. vitrata* and medium duration varieties with indeterminate growth habit (Maruti, TS-3(R) and WRP-1) were less susceptible. Saxena *et al.* (2002) reported higher damage by *M. vitrata* in determinate accessions than non-determinate. *M. vitrata* caused higher raceme damage in early (6.41%) and medium (4.17%) than late (0.91%) maturing varieties as observed by Sahoo and Senapati (2001). Srinivasa Rao *et al.* (2005) noticed the infestation of pod bugs on short duration varieties for shorter period. The incidence and damage by gram pod borer was high in medium maturing varieties (Reed and Lateef, 1990).

The flowering in these months also coincided with peak emergence of insect pests.

5.3.2 Per cent pod damage

The results of present findings clearly reveal that cultivars with long duration suffer to a greater extent by plume moth and pod fly as against short and medium duration. However, medium maturing hybrid (ICPH-2671) was prone to gram pod borer damage.

The least per cent pod damage by gram pod borer was noticed in long duration variety, BSMR-736, whereas highest damage was recorded in medium maturing hybrid, ICPH-2671. The early maturing, GC-11-39 cultivar sustained lesser damage by plume moth and pod fly. Plume moth caused highest pod damage in long duration variety, BSMR-736. The varieties with longer duration suffered to a greater extent by pod fly as exhibited in S-1 (Fig. 8).

Srinivasa Rao *et al.* (2003) observed higher pod damage by gram pod borer, plume moth and pod fly in long duration pigeonpea (15.60, 8.90 and 19.60%, respectively) followed by medium and short duration varieties. Similarly, Dar *et al.* (2005) and Srivastava and Joshi (2011) reported higher damage of pod fly in long duration and late maturing pigeonpea varieties.

Thus, use of these tolerant and high yielding cultivars could be most promising option for managing the insect pests of pigeonpea, which would also reduce the quantum of pesticide use and thereby, providing the ecological stability.
Fig 7: Performance of pigeonpea cultivars against major insect pests of pigeonpea (Pooled)

Fig 7: Performance of pigeonpea cultivars against major insect pests of pigeonpea (Pooled)
Fig 8: Performance of pigeonpea cultivars against different pod borers (Pooled)
5.4 Efficacy of various conventional insecticides against major insect pests of pigeonpea

4.4.1 Effect of various treatments on pests incidence

The different treatments comprising of three insecticides sprayed in sequence for evaluating their efficacy against major insect pests of pigeonpea under field conditions during 2011-12 and 2012-13.

5.4.1.1 Spotted pod borer, *Maruca vitrata* (Geyer)

The data on efficacy of conventional insecticides during first and second year revealed that, among the various insecticide tested in first spray, indoxacarb 14.5 SC (0.5 ml/l) and spinosad 45 SC (0.3 ml/l) were proved to be superior in reducing the incidence on spotted pod borer throughout the period of observation.

At second spray among the insecticides, DDVP 76 EC (0.5 ml/l) was found highly effective against spotted pod borer.

After second spray, there was gradual decline in incidence of spotted pod borer irrespective of the insecticides used and all the insecticides were found to be superior over untreated check during third spray.

The least per cent inflorescence damage (4.74%) due to *M. vitrata* was reported by Sreekanth and Seshamahalakshmi (2012) when spinosad 45 SC (73 g a.i/ha) was used. Similarly, Sunitha et al. (2008b) and Rao et al. (2007) reported the effectiveness of spinosad against legume pod borer, *M. vitrata*. Srinivasan and Philip Sridhar (2008) found the reduction (0.59 larvae/plant) in incidence of *M. vitrata* in DDVP (0.08%) treated plots over untreated check (2.00 larvae/plant).

5.4.1.2 Gram pod borer, *Helicoverpa armigera* (Hubner)

Among the eight insecticides assayed as a first spray against gram pod borer, indoxacarb 14.5 SC (0.5 ml/l) and spinosad 45 SC (0.3 ml/l) were found to be superior in reducing the larval density and were performed consistently throughout the period of observation after first spray.

Application of DDVP 76 EC (0.5 ml/l) as second spray was found to be superior over rest of the treatments at third days after spray (DAS), whereas *Bacillus thuringiensis* (2 kg/ha) performed better at seventh DAS and HaNPV (250 LE/ha) was highly effective at 14 DAS in eliminating pest load of the gram pod borer.

Among various insecticides used as third spray, indoxacarb 14.5 SC (0.5 ml/l), spinosad 45 SC (0.3 ml/l), emamectin benzoate 5 SG (0.2 g/l), flubendiamide 480 SC (0.1 ml/l) and cypermethrin 25 EC (1 ml/l) were emerged as the best treatments over rest of the insecticides.

The present results are in agreement with the observations made by Babariya et al. (2010) who reported highest mortality of 89 to 96 per cent of *H. armigera* in indoxacarb (0.0075%), which was followed by spinosad (0.009%) with 86 to 95 per cent mortality. Similarly Tamboli and Lelage (2008) noticed that spinosad 45 SC (90 g a.i./ha) was most potent insecticide in reducing the larval population (0.29 larvae/plant) followed by flubendamide 20 WDG (50 g a.i./ha) recording 0.47 larvae per plant and next promising treatment was indoxacarb 15 SC (75 g a.i./ha) with 0.58 larvae per plant. Patel (2006) also documented the effectiveness of spinosad 45 SC (73 g a.i./ha) and emamectin benzoate 5 SG (11 g a.i./ha) against *H. armigera*. The application of emamectin benzoate 5 SG (9.5 g a.i./ha) registered lowest number of larvae (0.48 larvae/plant) and pod damage (2.86%) by *H. armigera* (Barad et al., 2013). The efficacy of HaNPV (250 LE) against *H. armigera* was proved by Bijjur (1990) and Yelshetty et al. (2003).

5.4.1.3 Plume moth, *Exelastis atomosa* (May.)

Out of eight insecticides tested in second spray, DDVP 76 EC (0.5 ml/l) proved to be highly effective in reducing population density of plume moth upto 14 days of application.

The gradual decline in incidence of plume moth was noticed after third spray in all the treatments. Of the various insecticides evaluated under third spray, chlorpyriphos 20 EC (2.5 ml/l), indoxacarb 14.5 SC (0.5 ml/l), spinosad 45 SC (0.3 ml/l), profenophos 50 EC (2 ml/l), emamectin benzoate 5 SG (0.2 g/l), flubendiamide 480 SC (0.1 ml/l) and cypermethrin 25 EC (1 ml/l) were highly promising in eliminating the population of plume moth.
5.4.2 Efficacy of various treatments on pod damage and grain yield of pigeonpea

5.4.2.1 Pod damage

The spray sequence comprising of chlorpyriphos 20 EC (2.5 ml/l)- HaNPV (250 LE/ha)- spinosad 45 SC (0.3 ml/l) was found superior in reducing the per cent pod damage by gram pod borer. Plume moth caused minimum per cent pod damage in treatments, where nimbecidine 0.03 EC (3 ml/l), DDVP 76 EC (0.5 ml/l) and indoxacarb 14.5 SC (0.5 ml/l) were sprayed in sequence. The treatment sequence of quinolphos 25 EC (2 ml/l), DDVP 76 EC (0.5 ml/l) and profenophos 50 EC (2 ml/l) found to be superior against pod fly and significantly reduced the per pod damage (Fig. 9).

The present results are in confirmation with the findings of Bhoyar et al. (2004) who reported the effectiveness of spinosad 2.5 SC (25 g a.i./ha) in reducing the pod damage (11.80%). Dodia et al. (2009) also observed the least pod damage (7.35%) in spinosad 45 SC (73 g a.i./ha). Similarly, minimum pod damage of 5.62 per cent was observed in spinosad 45 SC (90 g a.i./ha) by Tamboli and Lolage (2008).

The lowest pod damage (16.3% and 17.00%) by pod fly was reported by Narasimhamurthy and Keval (2012) with spraying of spinosad 45% SC (73 g a.i./ha), followed by indoxocarb 14.5% SC (60 g a.i./ha) with 18.0 per cent and 17.3 per cent pod damage.

The effectiveness of HaNPV in reducing the pod damage by *H. armigera* was proved by Srinivasan and Philip Sridhar (2008) and Gajendran et al. (2006) and Bijjur (1990).

5.4.2.2 Grain yield

The highest grain yield was obtained from spray sequence, chlorpyriphos 20 EC (2.5 ml/l), HaNPV (250 LE/ha) and spinosad 45 SC (0.3 ml/l), which was followed by indoxacarb 14.5 SC (0.5 ml/l), HaNPV (250 LE/ha) and chlorpyriphos 20 EC (2.5 ml/l) (Fig. 10).

Dodia et al. (2009) reported highest grain yield of 1717 and 1598 kg per hectare from spinosad 45 SC and indoxacarb 14.5 SC treated plots. Similarly, Babariya et al. (2010) recorded highest grain yield of 1486 kg per hectare with indoxacarb (0.0075%) treatment which was followed by spinosad (0.009%) with 1451 kg per ha.

5.4.3 Cost effectiveness of various conventional insecticides in the management of major insect pests of pigeonpea during 2011-12 and 2012-13

The treatment, chlorpyriphos 20 EC (2.5 ml/l)- HaNPV (250 LE/ha)- spinosad 45 SC (0.3 ml/l) recorded highest net return and B:C ratio, which was followed by indoxacarb 14.5 SC (0.5 ml/l)- HaNPV (250 LE/ha)- chlorpyriphos 20 EC (2.5 ml/l).

Considerable advantage in net return through the use of indoxacarb 14.5 SC (0.5 ml/l) and spinosad 45 SC (0.3 ml/l) was reported by Dodia et al. (2009) and Narasimhamurthy and Keval (2012). Babariya et al. (2010) reported highest net return using indoxacarb (0.0075%) followed by spinosad (0.009%).

Therefore, the use of newer insecticides such as indoxacarb, spinosad, emamectin benzoate and flubendiamide were found to be advantageous because of lower dosage and high effectiveness.

5.5 Efficacy of various biorational insecticides against major insect pests of pigeonpea

5.5.1 Effect of various treatments on pests incidence

Various treatments comprising of three biorational insecticides sprayed in sequence for evaluating their efficacy against major insect pests of pigeonpea under field conditions during 2011-12 and 2012-13.

The spray application of nimbecidine 0.03 EC (3 ml/l) alone was found superior over untreated check in reducing the incidence of spotted pod borer, gram pod borer and plume moth.

The effectiveness of nimbecidine against *H. armigera* and plume moth was proved by Nath and Singh (2006) and Singh et al. (2012), respectively.
Fig. 9. Influence of conventional insecticides on pod damage by different pod borers in pigeonpea (pooled)

Fig 9: Influence of conventional insecticides on pod damage by different pod borers in pigeonpea (Pooled)
Fig. 10. Effect of conventional insecticides on grain yield of pigeonpea during 2011-12 and 2012-13

LEGEND

T₁ Bird perches - Hand collection of caterpillars
T₂ Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l)
T₃ Nimbecidine 0.03 EC (3ml/l) - DDVP 76 EC (0.5 ml/l) - Indoxacarb 14.5 SC (0.5 ml/l)
T₄ Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l)
T₅ Quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l) - Profenophos 50 EC (2 ml/l)
T₆ DDVP 76 EC (0.5 ml/l) - Bacillus thuringiensis (2 kg/ha) - Emamectin benzoate 5 SG (0.2 g/l)
T₇ Acephate 75 SP (1g/l) - Methomyl 40 SP (0.6 g/l) - Flubendiamide 480 SC (0.1 ml/l)
T₈ Spinosad 45 SC (0.3 ml/l) - Dicofol 18.5 EC (2.5 ml/l) - Cypermethrin 25 EC (1 ml/l)
T₀ Untreated check

Fig 10 : Effect of various conventional insecticides on grain yield of pigeonpea during 2011-12 and 2012-13
5.5.1.1 Spotted pod borer, *Maruca vitrata* (Geyer)

Among the various insecticides tested under second spray, *Beauveria bassiana* (2x10^8 spores/g) (2g/l) was found effective over untreated check in reducing the incidence of spotted pod borer, however it was statistically on par with rest of the insecticides.

There was gradual decline in incidence of spotted pod borer after third spray in all the treatments. The third spray consisted of two insecticides and flubendiamide 480 SC (0.1 ml/l) was proved to be highly effective in reducing the incidence of spotted borer followed by *Bacillus thuringiensis* (2kg/ha).

The present results are in agreement with the findings of Manjula and Padmavathamma (1996) who reported that *B. thuringiensis* and *B. bassiana* were effective against *M. testulalis*. Sreekanth and Seshamahalakshmi (2012) reported lowest per cent inflorescence (10.52% and 14.15%) damage due to the application of *B. thuringiensis* (1.5 kg/ha) and *B. bassiana* SC (300 mg/L) over untreated check. Similarly, the effectiveness of *B. thuringiensis* against *M. vitrata* was proved by Mohapatra and Srivastava (2008). Correspondingly, the lowest flower damage of 4.99 per cent by *M. testulalis* was recorded with flubendiamide 480 SC (100 ml/ha) by Ameta *et al.* (2011).

5.5.1.2 Gram pod borer, *Helicoverpa armigera* (Hubner)

Under second spray, *B. thuringiensis* (2 kg/ha) was found superior over rest of the treatments in reducing the larval density of gram pod borer at three days after spray. However, *HaNPV* (250 LE/ha) and *B. thuringiensis* (2 kg/ha) were found highly effective at seven days after spray. At 14 DAS, *HaNPV* (250 LE) performed better over rest of the treatments.

Under third spray, Flubendiamide 480 SC (0.1 ml/l) performed superior, which was followed by *B. thuringiensis* (2 kg/ha).

Similarly, Yadav (2009) reported the effectiveness of *HaNPV* (450 LE/ha) on 8th and 14th days after spraying. The reduction in larval density (0.70 larvae/plant) by applying *Bacillus thuringiensis* was reported by Thilagam and Kennedy (2007). The present findings on efficacy of flubendiamide 480 SC corroborate with those of Ameta *et al.* (2011), which caused maximum reduction in the population of *H. armigera* larvae in pigeonpea.

5.5.1.3 Plume moth, *Exelastis atomosa* (May.)

Second spray consisted of various entomopathogenic formulations and *B. bassiana* (2x10^8 spores/g) (2g/l) was found effective against plume moth over untreated check; however it was statistically on par with remaining treatments.

There was gradual decline in incidence of plume moth after third spray in all the treatments and flubendiamide 480 SC (0.1 ml/l) proved to be excellent in suppressing the incidence of plume moth.

4.5.2 Efficacy of various treatments on pod damage and grain yield of pigeonpea

5.5.2.1 Pod damage

The treatment sequence, nimbecidine 0.03 EC (3 ml/l)- *HaNPV* (250 LE/ha)- flubendiamide 480 SC (0.1 ml/l) and nimbecidine 0.03 EC (3 ml/l)- *B.t.* (2 kg/ha)- flubendiamide 480 SC (0.1 ml/l) was proved effective against gram pod borer and registered lowest per cent pod damage.

The treatment sequences, Nimbecidine 0.03 EC (3 ml/l)- *HaNPV* (250 LE)- Flubendiamide 480 SC (0.1 ml/l), Nimbecidine 0.03 EC (3 ml/l)- *B. bassiana* (2x10^8 spores/g) (2 g/l)- Flubendiamide 480 SC (0.1 ml/l), Nimbecidine 0.03 EC (3 ml/l)- *N. rileyi* (2x10^8 spores) (2g/l)- Flubendiamide 480 SC (0.1 ml/l) and Nimbecidine 0.03 EC (3 ml/l)- *B.t* (2 kg/ha).- Flubendiamide 480 SC (0.1 ml/l) were equally effective in reducing the pod damage by plume moth and pod fly (Fig. 11).

The effectiveness of flubendiamide in minimizing the pod damage due to *H. armigera* was proved by Dodia *et al.* (2009) and Ameta *et al.* (2011).

5.5.2.2 Grain yield

Significantly higher grain yield was obtained in a spray sequence of Nimbecidine 0.03 EC (3 ml/l)- *HaNPV* (250 LE/ha)- Flubendiamide 480 SC (0.1 ml/l) and Nimbecidine 0.03 EC (3ml/l)- *B.t.* (2 kg/ha)- Flubendiamide 480 SC (0.1 ml/l) (Fig. 12).
Fig. 11. Influence of biorational insecticides on pod damage by different pod borers in pigeonpea (pooled)

**LEGEND**

T1  Nimbecidine 0.03 EC (3ml/l) - Ha-HPV (250 LE) - Bacillus thuringiensis (B.t.) (2 kg/ha)
T2  Nimbecidine 0.03 EC (3ml/l) - Beauveria bassiana (2x10^8 spores/g) (2g/l) - B.t (2 kg/ha)
T3  Nimbecidine 0.03 EC (3ml/l) - Nomuraea rileyi (2 x10^8 spores/g) (2g/l) - B.t. (2 kg/ha)
T4  Nimbecidine 0.03 EC (3ml/l) - Metarhizium anisopliae (2 x10^8 spores/g) (2g/l) - B.t. (2 kg/ha)
T5  Nimbecidine 0.03 EC (3ml/l) - HaNPV (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)
T6  Nimbecidine 0.03 EC (3ml/l) - B. bassiana (2x10^8 spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)
T7  Nimbecidine 0.03 EC (3ml/l) - N. rileyi (2 x10^8 spores) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)
T8  Nimbecidine 0.03 EC (3ml/l) - B. t. (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)
T9  Untreated check

Fig 11 : Influence of biorational insecticides on pod damage by different pod borers in pigeonpea (Pooled)
Fig. 12. Effect of biorational insecticides on grain yield of pigeonpea during 2011-12 and 2012-13

**LEGEND**

- **T1**: Nimbecidine 0.03 EC (3ml/l) - Ha-NPV (250 LE) - Bacillus thuringiensis (B.t.) (2 kg/ha)
- **T2**: Nimbecidine 0.03 EC (3ml/l) - Beauveria bassiana (2x10^8 spores/g) (2g/l) - B.t. (2 kg/ha)
- **T3**: Nimbecidine 0.03 EC (3ml/l) - Nomuraea rileyi (2 x10^8 spores/g) (2g/l) - B.t. (2 kg/ha)
- **T4**: Nimbecidine 0.03 EC (3ml/l) - Metarhizium anisopliae (2 x10^8 spores/g) (2g/l) - B.t. (2 kg/ha)
- **T5**: Nimbecidine 0.03 EC (3ml/l) - HaNPV (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l)
- **T6**: Nimbecidine 0.03 EC (3ml/l) - B. bassiana (2x10^9 spores/g) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)
- **T7**: Nimbecidine 0.03 EC (3ml/l) - N. rileyi (2 x10^8 spores) (2g/l) - Flubendiamide 480 SC (0.1 ml/l)
- **T8**: Nimbecidine 0.03 EC (3ml/l) - B. thuringiensis (2 kg/ha) - Flubendiamide 480 SC (0.1 ml/l)
- **T9**: Untreated check

**Fig 12**: Effect of biorational insecticides on grain yield of pigeonpea during 2011-12 and 2012-13 (Pooled)
Similarly, Ameta et al. (2011) recorded highest grain yield (12.15 q/ha) in flubendiamide 480 SC (100 ml/ha) treated plots.

5.5.3 Cost effectiveness of various biorational insecticides in the management of major insect pests of pigeonpea during 2011-12 and 2012-13

The treatment sequence, Nimbecidine 0.03 EC (3 ml/l)- HaNPV (250 LE)- Flubendiamide 480 SC (0.1 ml/l) registered highest net return and B:C ratio, which was followed by Nimbecidine 0.03 EC (3 ml/l)- B t.(2 kg/ha)- Flubendiamide 480 SC (0.1 ml/l).

Dodia et al. (2009) reported highest B:C ratio (1.45) when flubendamide 20 WDG (50 g a.i./ha) was used in the management of pod borers in pigeonpea.

The studies on field efficacy of various insecticides revealed that the newer insecticides indoxacarb, spinosad, emamectin benzoate, flubendiamide were highly effective in managing the lepidopteran insect pests of pigeonpea. Among the entomopathogens, HaNPV and B. thuringiensis were found superior against H. armigera.

Despite the superiority of synthetic newer insecticides in managing the insect pests of pigeonpea, it is advisable to adopt the sequential spraying of insecticides involving botanicals, entomopathogens and synthetic insecticides for managing the resistant insect species, achieving the higher yield and ecological sustainability.

Future line of work

1) Detailed studies on flower webber, Maruca vitrata (Geyer) and pod fly Melanagromyza obtusa (Malloch) is need to be done as they are emerging as one of the serious pests in zone eight

2) Studies on biochemical and biophysical basis for resistance in tolerant pigeonpea cultivars

3) Determination of ETL and development of IPM modules for major insect pests of pigeonpea specific to zone eight and studies on intercropping as a cultural component of pest management as the pigeonpea crop in being grown as an intercrop in zone eight

4) Detailed studies on arthropod biodiversity in pigeonpea ecosystem.
SUMMARY AND CONCLUSIONS

Studies on survey, seasonal incidence, varietal screening and management of major insect pests of pigeonpea in the northern transitional zone of Karnataka were carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad between 2011 and 2013 with the following objectives: 1) survey of major insect pests of pigeonpea in the selected districts of northern transitional belt of Karnataka, 2) seasonal abundance of major insect pests of pigeonpea in northern transitional belt of Karnataka, 3) varietal screening to identify the tolerance level of important cultivars, 4) management of insect pests by conventional approach and 5) management of insect pests by biorational approach. The results of the findings are summarized hereunder.

The two year (2011-12 and 2012-13) survey carried out at Belgaum, Dharwad and Haveri districts of northern transitional tract (Zone-8) of Karnataka revealed the presence of insect pests such as ash weevil (*Myloecerus discolor* F.), leaf webber (*Grapholita critica* Meyr), hairy caterpillars (*Amsacta* spp.), aphids (*Aphis craccivora* Koch), bud weevil (*Ceuthorhynchus asperulus* (Faust)), spotted pod borer (*Maruca vitrata* (Geyer)), gram pod borer (*Helicoverpa armigera* Hubner), pod bugs (*Clavigralla gibbosa* Spinola, *Riptortus pedestris* (F.) and *Anoplocnemis phasiana* (Fabricius)), blister beetle (*Mylabris pustulata* (Thunberg)) and plume moth (*Exelastis atomosa* (May.)) at different stages of crop growth. The higher incidence of insect pest was recorded in Haveri followed by Dharwad District and lower incidence was recorded in Belgaum.

The maximum activity of hairy caterpillars noticed at 34th week (August) and 36th week (September) during first and second year study. The leaf webber reached its peak during 35th (August) and 37th week (September) during first and second year at the vegetative stage of the crop. The highest incidence of spotted pod borer recorded during 45th (November) and 47th week (November) during first and second year of study at the flowering stage of the crop. The peak population of bud weevil, gram pod borer and pod bugs was recorded at 47th week (November), 48th week (November) and 44th week (November), respectively for both the years of study. The peak activity of blister beetle was noticed at 45th (November) and 44th week (November) during first and second year of study. The maximum population of plume moth was noticed at 47th (November) and 48th week (November) during first and second year of study period.

The correlation and regression studies revealed that, during the first year of study, minimum temperature and relative humidity had positive correlation with leaf webber incidence. The maximum temperature showed positive correlation with gram pod borer population. The increase in relative humidity favoured the population buildup of hairy caterpillar during first year of study. However, during the second year the increase in mean minimum temperature favoured the incidence of hairy caterpillar and leaf webber.

The incidence of gall weevil, hairy caterpillar, leaf webber, spotted pod borer, gram pod borer, pod bugs and plume moth was least in early sown crop (first week of June, third week of June and first week of July). Further higher incidence was noticed in delayed sowing (third week of July and first week of August). However, the effect of date of sowing on the incidence of bud weevil and blister beetle was not clearly evident.

Similarly, the pod borers such as gram pod borer and plume moth inflicted least pod damage in early sown crop (first week of June, third week of June and first week of July). Further higher incidence was noticed in delayed sowing (third week of July and first week of August). However, the effect of date of sowing on the incidence of bud weevil and blister beetle was not clearly evident.

The higher grain yield of pigeonpea was obtained in early sown (first and third week of June) crop and was decreased with delayed sowing. Thus early sowing could be an effective non monetary input for achieving higher yield with minimizing pest load in pigeonpea.

A total of 31 insect pests were recorded during the course of investigation, of which 13 insect pests belonged to lepidoptera, eight belonged to hemiptera, six belonged to coleoptera and one each from diptera, thysanoptera, hymenoptera and orthoptera.

The larval parasitoids such as *Campoletis chlorideae* Uchida, *Apanteles* sp., tachinid fly and egg parasitoid, *Telenomus* sp. were recorded on *Helicoverpa armigera* (Hubner). The larval parasitoid *Apanteles taragamae* Viereck recorded on *Maruca vitrata* (Geyer) and *Glyptapanteles* sp. from hairy caterpillar (Arctiidae) larvae.
The arthropod predators such as lady bird beetle, Cheilomenes sexmaculata (Fabricius), green lacewing, Crysoperla carnea (Stephens), reduvid bug, dragonfly and spiders were recorded from pigeonpea ecosystem.

The predatory birds, black drongo (Dicrurus macrocercus (Vieillot)), green bee eater (Merops orientalis (Latham)), mynah (Acridotheres tristis (Linnaeus)) and crow (Corvus splendens (Vieillot)) were noticed during the study period.

The incidence of spotted pod borer was high in early maturing cultivar, GC-11-39 and least in ICP-8863. The incidence of leaf webber and gram pod borer was high in hybrid, ICPH-2671 and least in BSMR-736. The higher incidence of pod bugs and plume moth was noticed in BSMR-736 and S-1. The hybrid, ICPH-2671 recorded higher incidence of bud weevil.

The least pod damage by gram pod borer was noticed in BSMR-736, while highest damage was recorded in hybrid, ICPH-2671. The pod damage by plume moth and pod fly was least in GC-11-39. Plume moth inflicted highest pod damage in BSMR-736 and pod fly inflicted higher injury in S-1.

The insecticides such as DDVP 76 EC (0.5 ml/l), chlorpyriphos 20 EC (2.5 ml/l), indoxacarb 14.5 SC (0.5 ml/l), spinosad 45 SC (0.3 ml/l), and DDVP 76 EC (0.5 ml/l) were found effective against spotted pod borer.

The insecticides like indoxacarb 14.5 SC (0.5 ml/l), spinosad 45 SC (0.3 ml/l), DDVP 76 EC (0.5 ml/l), Bacillus thuringiensis (2 kg/ha), HaNPV (250 LE/ha), emamectin benzoate 5 SG (0.2 g/l), flubendiamide 480 SC (0.1 ml/l) and cypermethrin 25 EC (1 ml/l) were emerged as promising insecticides for the management of gram pod borer which can be used as an effective tool of IPM.

The insecticides such as DDVP 76 EC (0.5 ml/l), chlorpyriphos 20 EC (2.5 ml/l), indoxacarb 14.5 SC (0.5 ml/l), spinosad 45 SC (0.3 ml/l), profenophos 50 EC (2 ml/l), emamectin benzoate 5 SG (0.2 gm/l), flubendiamide 480 SC (0.1 ml/l) and cypermethrin 25 EC (1 ml/l) were found effective in suppressing the plume moth.

The spray sequence, chlorpyriphos 20 EC (2.5 ml/l)- HaNPV (250 LE/ha) -spinosad (0.3 ml/l) was effective in reducing the pod damage by gram pod borer and resulted in higher grain yield and B:C ratio, whereas the spray sequence nimbecidine 0.03 EC (3 ml/l)- DDVP 76 EC (0.5 ml/l)- indoxacarb 14.5 SC (0.5 ml/l) and quinolphos 25 EC (2 ml/l) - DDVP 76 EC (0.5 ml/l)- profenophos 50 EC (2 ml/l) was found promising against plume moth and pod fly, respectively.

Among the various biorational insecticides evaluated, the sequence- nimbecidine 0.03 EC (3 ml/l), Beauveria bassiana (2x10^8 spores/g) (2 g/l) and flubendiamide 480 SC (0.1 ml/l) was found highly effective against spotted pod borer and plume moth.

The treatment sequences, nimbecidine 0.03 EC (3 ml/l)- HaNPV (250 LE/ha) -flubendiamide 480 SC (0.1 ml/l) and nimbecidine 0.03 EC (3 ml/l) - B.t (2 kg/ha) -flubendiamide 480 SC (0.1 ml/l) were effective in reducing the pod damage by gram pod borer and resulted in higher grain yield and economic returns. The sequence, nimbecidine 0.03 EC (3ml/l)- B. bassiana (2g/l)- flubendiamide 480 SC (0.1 ml/l) was performed better against plume moth and pod fly.

Conclusions

- The pest spectrum of pigeonpea in the northern transitional zone included 31 insect pest distributed across the seven insect orders.
- The parasitoids reported were Campoletis chlorideae Uchida, Apanteles sp., lachinid fly and Telenomus sp. on Helicoverpa armigera (Hubner). The larval parasitoid Apanteles taragamae Viereck recorded on Maruca vitrata (Geyer) and Glyptapanteles sp. from hairy caterpillar (arctiidae) larvae.
- The arthropod predators, lady bird beetle, Cheilomenes sexmaculata (Fabricius), green lacewing, Crysoperla carnea (Stephens), reduvid bug, dragonfly and spiders were recorded from pigeonpea ecosystem.
- The predatory birds were black drongo (Dicrurus macrocercus (Vieillot)), green bee eater (Merops orientalis (Latham)), mynah (Acridotheres tristis (Linnaeus)) and crow (Corvus splendens (Vieillot)).
- The incidence of gall weevil (Alcidodes collaris Pascoe), hairy caterpillar (Amsacta sp.), leaf webber (Grapholita critica (Meyr)), spotted pod borer (M. vitrata), gram pod borer (H.
armigera), pod bugs (Anoplocnemis phasiana (Fabricius), Riptortus pedestris (F.) and Clavigralla gibbosa Spinola), plume moth (Exelastis atomosa (May.)) and pod fly (Melanagromyza obtusa (Malloch)) was least on the crop sown during first week of June, third week of June and first week of July. The grain yield of pigeonpea was decreased with delay in sowing beyond July first week.

- The insect pests like gall weevil, A. collaris, flower webber (spotted pod borer), M. vitrata and leaf webber, G. critica were found to be the emerging insect pests of pigeonpea in the transitional zone of Karnataka.
- The insect pests such as gram pod borer, H. armigera, pod fly, M. obtusa and plume moth, E. atomosa were major pod borers of pigeonpea in the transitional zone.
- Among the different cultivars screened, the least inflorescence damage by spotted pod borer noticed on medium duration cultivar, ICP-8863. The long duration cultivar, BSMR-736 suffered lesser damage by leaf webber and gram pod borer. The incidence of bud weevil, pod bugs, plume moth and pod fly was least in early maturing cultivar, GC-11-39.
- Among the conventional insecticides, the spray sequence Chlorpyriphos 20 EC (2.5 ml/l) - HaNPV (250 LE/ha) - Spinosad 45 SC (0.3 ml/l) was proved economical in managing the insect pests of pigeonpea followed by Indoxacarb 14.5 SC (0.5 ml/l) - HaNPV (250 LE/ha) - Chlorpyriphos 20 EC (2.5 ml/l).
- Among the biorational insecticides, the sequence Nimbecidine 0.03 EC (3 ml/l) - HaNPV (250 LE/ha) - Flubendiamide 480 SC (0.1 ml/l) and Nimbecidine 0.03 EC (3 ml/l) - B. t. (2 kg/ha)- Flubendiamide 480 SC (0.1 ml/l) were emerged as the economical and effective treatments in managing the insect pests of pigeonpea.

Thus, a pest management strategy involving cultural practices such as adjustment in date of sowing, use of tolerant cultivars and three sprays of insecticides comprising of conventional insecticides, botanicals, entomopathogens and newer insecticides in sequence, based on the economic threshold level of the pest forms better choice in managing the insect pests of pigeonpea and achieving the optimum yield. The combination of botanicals, entomopathogens and newer insecticides may help in managing the resistant insect pest like gram pod borer, H. armigera in an economical way.
REFERENCES


Anantharaju, P. and Muthiah, A. R., 2008, Biochemical components in relation to pests incidence of pigeonpea spotted pod borer (Maruca vitrata) and blister beetle (Mylabris spp.). *Legume Res.*, 31(2) : 87-93.


Appendix I: The meteorological data obtained from Main Agriculture Research Station, Dharwad, Karnataka (India)

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MSW: Meteorological Standard Week
ABSTRACT

Investigation on survey, seasonal incidence, varietal screening and management of insect pests of pigeonpea in the northern transitional zone of Karnataka was carried out at MARS, UAS, Dharwad during 2011 to 2013.

The pest spectrum of pigeonpea in the northern transitional zone included 31 insect pests belonging to orders lepidoptera, hemiptera, coleopteran, diptera, thysanoptera, hymenoptera and orthoptera. The survey studies revealed that the highest population of insect pests on pigeonpea was recorded in Haveri followed by Dharwad and lowest in Belgaum district.

The peak activity of pod borer, *Helicoverpa armigera* (Hubner) was observed during 48th week (November) for both the years of study. The maximum population of plume moth was noticed at 47th (November) and 48th week (November) during first and second year. The influence of different dates of sowing on pest incidence revealed that the early sown pigeonpea crop (1st week of June, 3rd week of June and 1st week of July) registered lower incidence of pest and higher grain yield.

The field screening of pigeonpea cultivars for their tolerance to pest damage revealed that ICP-8863 registered least inflorescence damage by flower webber, *Maruca vitrata* (Geyer). The cultivar, BSMR-736 suffered with lesser damage by leaf webber (*Grapholita critica* Meyr.) and gram pod borer (*H. armigera*). The incidence of bud weevil, *Ceuthorhynchus asperulus* (Faust), pod bugs (*Anoplocnemis phasiana* (Fabricius), *Riptortus pedestris* (F.) and *Clavigralla gibbosa* Spinola), plume moth, *Exelastis atomosa* (May.) and pod fly, *Melanagromyza obtusa* (Malloch) was least on cultivar, GC-11-39.

The efficacy of different insecticides tested revealed that indoxacarb 14.5 SC (0.5 ml/l), spinosad 45 SC (0.3 ml/l), emamectin benzoate 5 SG (0.2 g/l) and flubendiamide 480 SC (0.1 ml/l) were highly effective against *H. armigera*. Among the entomopathogens tested, *HaNPV* (250 LE/ha) and *Bacillus thuringiensis* (2.0 kg/ha) were found superior in suppressing the population of *H. armigera*. 