Impact of Different IPM Modules on Natural Enemies of *Helicoverpa armigera* (Hubner) in Pigeonpea Ecosystem in Andhra Pradesh, India

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Abstract

Some IPM modules were field evaluated against *Helicoverpa armigera* and impact of these modules were worked out on its natural enemies in pigeon pea at ARS, Tandur during *kharif* 2007-08, extent of damage caused by *H.armigera* and yield attributes were also worked out. The results revealed that Bio Intensive Pest Management (BIPM) module was ultimately the promising one with better net returns (Cost:Benefit ratio 1:1.20) and effective conservation of natural enemies even though, Farmers Practice (FP) and Integrated Pest Management (IPM) modules initially hosted less larval populations and minimum extent of damage indicating the suitability and feasibility of BIPM for pigeon pea ecosystems by augmenting natural enemies.

1. Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the most important food legume crops in India. Gram pod borer, *H. armigera* causes colossal losses in the yield of pigeon pea to the tune of 60-90% (Anonymous, 1994). Despite the fact that chemicals proved their potential to avert the insect pests on pigeonpea (Patil et al*.,* 1990), any single method of approach to pest control may not be feasible, hence the best alternative is Integrated Pest Management (IPM) approach, which is based on the principles of managing the pest rather than aiming at complete eradication. In this direction, extensive studies are in progress to develop IPM modules containing all possible components like use of resistant varieties, cultural and mechanical control, biological suppression, chemical control, behavioral approach etc., (Jayaraj, 1992) which ultimately help in reducing the negative influence of insecticides on the natural enemies that are present in the suitable ecological niche and will protect the eco-systems and the environment from toxicological hazards. Thus, in view of sustaining productivity of pigeon pea with minimal adverse effects on the environment there is an imperative need to develop and evaluate various IPM strategies, ably incorporating options from plant and microbial origin. Even though, certain efforts are made in this direction, crop and location specific studies are the need of the hour. Hence, the present study is proposed and carried out to generate information on the incorporation of eco-friendly inputs individually and their sequence in IPM modules against natural enemies of *H. armigera* in pigeonpea ecosystem.

2. Materials and Methods

The experiment was laid out at ARS, Tandur farm**.** A total area of 800 m^2 was divided into four blocks, each block measuring 200 m^2 (20 m×10 m) to act as treatment for four different modules. Sowing was taken up during *kharif* July 2007-08 with a high yielding variety Asha (ICPL-87119) simultaneously gap filling and thinning were done allowing one seedling per hill. Spacing adopted was 1.0 m×20 cm between the rows and between the plants. Different modules tested were as follows:

2.1. BIPM module

- Deep ploughing and exposure of soil to hot summer to kill pupating larvae.

- Prior to sowing, seed treatment with *Trichoderma viride* @ 10g per kg of seed for controlling pigeonpea wilt.
- Intercropping of pigeonpea and jowar in the ratio of 1:2
- Using marigold as trap crop on border for pod borer control.
- Installation of pheromone traps @ 10 ha^{-1} in the month of September.
- Erection of bird perches @ 25 ha^{-1} for predation of *H. armigera* larvae.
- Mechanical shaking of plants to dislodge *H. armigera* larvae.
- Spray of *Ha*NPV @ 250 LE(1.5×10^{12} POBs ml^{-1})
- Spray of sequence *Ha*NPV-*Bt*-*Ha*NPV
- Spray of endosulfan @ 2ml l^{-1}

2.2. IPM module

- Deep ploughing and exposure of soil to hot summer to kill pupating larvae
- Installation of pheromone traps @ 10 ha^{-1} in the month of September.
- Erection of bird perches @ 25 ha^{-1} for predation of *H. armigera* larvae.
- Two applications of NSKE 5% in the month of September.
- Mechanical shaking of plants to dislodge *H. armigera* larvae
- Spray of *Ha*NPV @ 250 LE(1.5×10^{12} POBs ml^{-1})
- Spray of endosulfan @ 2ml l^{-1}

2.3. Farmers practice module

- The plant protection measures adopted by the local farmers were followed in FP module at 10 days interval

First spray	:	endosulfan (2 ml l^{-1})
Second spray	:	quinalphos (2 ml l^{-1})
Third spray	:	spinosad (0.3 ml l^{-1})
Fourth spray	:	indoxacarb (1 ml l^{-1})
Fifth spray	:	spinosad (0.3 ml l^{-1})

2.4. Control module

- A control module with no inputs either chemical or non chemical was also kept for the purpose of comparison between the test modules.

Each block consisting of one test module was divided into five different strata by selecting 25 m^2 as one stratum (approximately 10 plants $strata^{-1}$) and the data were recorded on incidence of natural enemies and extent of damage by gram pod borer. Similarly, yield attributes were also recorded to know the impact of the test modules on productivity.

2.5. Influence of certain eco-friendly inputs on extent of damage by H. armigera in pigeonpea

The efficacy module was also studied in terms of the extent of damage caused by the pest. The method suggested by Bindra and Jakhmola (1967) was adopted to specify the damage caused by *H. armigera.*

2.5.1. Per cent pod damage

Pod damage was calculated from the tagged ten plants randomly from the unit plot and were harvested separately and labelled. The labelled covers with pods from ten randomly selected plants were brought to the laboratory where, total number of pods, number of healthy pods and number of damaged pods were counted. Pod borer infested pods were identified on the basis of circular hole comparatively of bigger size made on the pod. The per cent pod damage was worked out for each treatment by using the formula:

$$\text{Per cent pod damage} = \frac{\text{Number of damaged pods}}{\text{Number of total pods examined}} \times 100$$

2.5.2. Per cent grain damage

The assessment of damage to the grains caused by pod borer was calculated by collecting 100 pod samples randomly from each plot, were counted and per cent grain damage was calculated by using the formula:

$$\text{Per cent grain damage} = \frac{\text{Number of locules without grains or partially damaged grains}}{\text{Total number of locules from 100 pods}} \times 100$$

2.5.3. Per cent seed damage

The damage caused to the seeds by pod borer was assessed by counting the number of healthy and damaged seeds from 100 pod samples selected randomly from each plot and per cent seed damage was computed by using the formula:

$$\text{Per cent seed damage} = \frac{\text{Number of infested seeds out of 100 pods examined}}{\text{Total number of seeds out of 100 pods}} \times 100$$

2.5.4. Per cent seed mass loss

Per cent seed mass loss was calculated by weighing healthy seeds and pod borer damaged seeds from 100 pod samples collected randomly from each plot.

$$\text{Percent seed mass loss} = \frac{\text{Mass of damaged seeds}}{\text{Mass of healthy seeds}} \times 100$$

2.6. Impact of different modules on yield attributes in pigeonpea

The yield attributes in pigeonpea *viz.,* total yield and yield gain were also compared among different treatments to assess the impact of the eco-friendly inputs on *H. armigera* infestation and natural enemies.

2.6.1. Yield

At maturity, harvesting and threshing was done plot wise. The threshed grains were cleaned, weighed and net plot yields were obtained. The pods collected from ten plants for the damage assessment were also threshed, cleaned and weighed separately and these weights were added to the net plot yield to get the total yield of the plot. The grain yield data were converted to kg ha^{-1} and analyzed statistically.

2.6.2. Yield gain

Yield gains were calculated based on the differences between sprayed and unsprayed plots expressed as proportions of the unsprayed plot yields. Thus

$$\text{Yield gain} = \frac{\text{Yield in sprayed plot - Yield in unsprayed plot}}{\text{Yield in unsprayed plot}} \times 100$$

2.6.3. Per cent avoidable loss

Per cent avoidable loss in grain yield due to pod borer in individual treatment in relation with most effective treatment was calculated by using the formula suggested by Pawar et al. (1984).

$$\text{Percent avoidable loss in grain yield} = \frac{y - y'}{y} \times 100$$

where y = Mean grain yield in most effective treatment

y'= Mean grain yield in respective treatment

2.6.4. Additional yield over control (kg ha^{-1})

It was calculated by substracting yield in control treatment from respective treatments and expressed in kg ha^{-1}.To know the economics of different treatments or modules, the quantity and cost of the insecticides as well as microbial pesticides for all the sprays in third objective was calculated and the cost incurred on labour charges for spraying were taken into consideration. The income was calculated by considering the prevailing market price of the produce obtained in different modules. The costs and benefits were tabulated and their ratio was calculated and compared for the economic validation of the effective module.

3. Results and Discussion

3.1. Impact of different test modules on the abundance of reduviid bugs in pigeonpea eco-system

The results with regard to the abundance of reduviid bugs (Table 1) has shown that their population during first week of observation were maximum in BIPM module (1.24 plant^{-1}) followed by IPM module with 1.06 bugs plant^{-1}. Minimal bug population was recorded in FP module (0.84 plant^{-1}). Control module recorded 1.56 bugs plant^{-1}. During second week of observation maximum bug population was recorded in BIPM module with 1.60 plant^{-1} followed by IPM module (1.38 bugs plant^{-1}). Minimal bug population was recorded in FP module (1.14 bugs plant^{-1}) whereas control module recorded 1.70 bugs plant^{-1}. During the third week of observation, maximum population of reduviid bugs was observed in BIPM module (1.84 bugs plant^{-1}) followed by IPM module with 1.64 bugs plant^{-1}. Minimal bug population was recorded in FP module with 1.30 bugs plant^{-1}. However, it was observed that bug population recorded in BIPM, IPM and control module were found to be on par but significantly different from FP module. During the fourth week of observation, maximum bug population was recorded in BIPM module (2.18 bugs plant^{-1}) followed by IPM module (2.06 bugs plant^{-1}). Minimal bug population was recorded in FP module with 1.60 bugs plant^{-1} whereas control module recorded 2.28 bugs plant^{-1}. However, the bug population recorded in BIPM and control module were found to be on par but significantly different from other modules.

During fifth week of observation, maximum bug population was recorded in BIPM module with 2.12 bugs plant^{-1} followed by IPM module (1.88 bugs plant^{-1}). Minimal bug population was recorded in FP module with 1.44 bugs plant^{-1}. Control module recorded 2.14 bugs plant^{-1}. However, it was documented that the bug population recorded in control module and BIPM module were found to be on par but significantly different from other modules. During sixth week of observation, maximum bug population was recorded in BIPM module (2.06 bugs plant^{-1}) followed by IPM module with 1.86 bugs plant^{-1}. Minimal bug population was recorded in FP module with 1.34 plant^{-1} whereas control module recorded 2.00 bugs plant^{-1}. However, it was observed that the bug population recorded in BIPM and control module were found to be on par but significantly different from other modules. During seventh week of observation, maximum bug population was recorded in BIPM module with 1.70 bugs plant^{-1} followed by IPM module with 1.54 bugs plant^{-1}. Minimal bug population was recorded in FP module with 1.20 bugs plant^{-1}. Control module recorded 1.76 bugs plant^{-1}. However, the population of reduviid bugs recorded in BIPM and IPM, BIPM and control module were found to be on par but significantly different from FP module. During eighth week of observation, maximum population was recorded in BIPM and IPM module with 1.34 and 1.26 bugs plant^{-1} which were found to be on par. Minimal population was recorded in FP module with 0.46 larvae plant^{-1}. Control module recorded 1.76 bugs plant^{-1}. However, it was observed that the bug population recorded in BIPM and IPM module were found to be on par but significantly different from other modules.

The mean population of reduviid bugs recorded in BIPM module was maximum (1.76 plant^{-1}) followed by IPM module with 1.48 bugs plant^{-1}. Minimal bug population was recorded in FP module (1.16 bugs plant^{-1}) whereas control module recorded 1.88 bugs plant^{-1}. However, it was observed that the bug population recorded in BIPM module was found to be on par with control module but significantly different from other modules.

3.2. Impact of different test modules on the abundance of coccinellid beetles in pigeonpea eco-system

The results pertaining to the abundance of coccinellid beetles (Table 2) has revealed that their population during first week of observation was the maximum in BIPM module (1.64 beetles plant^{-1}) followed by IPM module with 1.48 beetles plant^{-1}. Minimal coccinellid beetles plant^{-1} was observed in FP module with 0.90 beetles plant^{-1} whereas control module recorded 1.76 beetles plant^{-1}. During second week of observation, maximum population of coccinellid beetles was observed in BIPM module (1.78 beetles plant^{-1}) followed by IPM module with 1.60 beetles plant^{-1}. Minimal beetle population was recorded in FP module with 1.08 plant^{-1} whereas untreated control recorded 1.88 beetles plant^{-1}. During third week of observation maximum population of coccinellid beetles was observed in BIPM module with 2.00 beetles plant^{-1} followed by IPM module (1.94 plant^{-1}). Minimum population was recorded in FP module with 1.24 beetles plant^{-1} whereas control module recorded 1.98 beetles plant^{-1}. However, it was documented that the population of coccinellid beetles recorded in BIPM, IPM and control module were found to be on par but significantly different from FP module. During fourth week of observation, maximum population of coccinellid beetles was observed in BIPM module (2.32 beetles plant^{-1}) followed by IPM module with 2.12 beetles plant^{-1}. Minimal coccinellid n par but significantly different from other modules.

During fifth week of observation, maximum population of coccinellid beetles was observed in BIPM module (1.76 beetles plant^{-1}) followed by IPM module with 1.72 beetles plant^{-1}. Minimal coccinellid beetles plant^{-1} was observed in FP module with 1.44 beetles plant^{-1} whereas control module recorded 2.10 beetles plant^{-1}. However, it was documented that the coccinellid beetles recorded in BIPM and IPM modules were found to be on par but significantly different from other modules. During sixth week of observation, maximum population of coccinellid beetles was observed in BIPM module (1.56 beetles plant^{-1}) followed by IPM module with 1.32 beetles plant^{-1}. Minimal coccinellid beetles plant^{-1} was observed in FP module with

Table 1: Impact of different test modules on the abundance of reduviid bugs in pigeonpea eco-system during *kharif* 2007-08

Module	Period of observations*								
	Week I	Week II	Week III	Week IV	Week V	Week VI	Week VII	Week VIII	Mean
Bio Intensive pest Management (BIPM)	1.24[b]	1.60[ab]	1.84[a]	2.18[a]	2.12[a]	2.06[a]	1.70[ab]	1.34[b]	1.76[a]
	(1.31)	(1.44)	(1.52)	(1.63)	(1.61)	(1.59)	(1.48)	(1.35)	(1.49)
Integrated Pest Management (IPM)	1.06[bc]	1.38[bc]	1.64[a]	2.06[b]	1.88[b]	1.04[b]	1.86[b]	1.26[b]	1.48[b]
	(1.24)	(1.37)	(1.46)	(1.59)	(1.54)	(1.52)	(1.53)	(1.32)	(1.40)
Farmers Practice (FP)	0.84[c]	1.14[c]	1.30[b]	1.60[c]	1.44[c]	1.34[c]	1.20[c]	0.46[c]	1.16[c]
	(1.15)	(1.27)	(1.33)	(1.44)	(1.39)	(1.35)	(1.30)	(0.96)	(1.28)
Control	1.56[a]	1.70[a]	1.86[a]	2.28[a]	2.14[a]	2.00[a]	1.76[a]	1.76[a]	1.88[a]
	(1.43)	(1.48)	(1.53)	(1.66)	(1.62)	(1.58)	(1.50)	(1.50)	(1.54)
SEm±	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.03	0.02
CD (p=0.05)	0.09	0.10	0.09	0.03	0.03	0.03	0.07	0.10	0.07

*Mean of 50 plants. Values in the parentheses are square root transformed values. Values denoted by common letter are statistically on par at 0.05% as per DMRT

Table 2: Impact of different test modules on the abundance of coccinellid beetles in pigeonpea eco-system during *kharif* 2007-08

Module	Period of observations*								
	Week I	Week II	Week III	Week IV	Week V	Week VI	Week VII	Week VIII	Mean
Bio Intensive pest Management (BIPM)	1.64[ab]	1.78[ab]	2.00[a]	2.32[a]	1.76[b]	1.56[b]	1.20[b]	0.94[b]	1.65[b]
	(1.46)	(1.50)	(1.58)	(1.67)	(1.50)	(1.43)	(1.30)	(1.19)	(1.45)
Integrated Pest Management (IPM)	1.48[b]	1.60[b]	1.94[a]	2.12[b]	1.72[b]	1.32[bc]	1.02[b]	0.76[b]	1.49[b]
	(1.40)	(1.44)	(1.56)	(1.61)	(1.48)	(1.34)	(1.23)	(1.12)	(1.40)
Farmers Practice (FP)	0.90[c]	1.08[c]	1.24[b]	1.68[c]	1.44[c]	1.26[c]	0.84[c]	0.44[c]	1.11[c]
	(1.18)	(1.25)	(1.31)	(1.47)	(1.39)	(1.32)	(1.15)	(0.96)	(1.26)
Control	1.76[a]	1.88[a]	1.98[a]	2.38[a]	2.10[a]	1.94[a]	1.82[a]	1.34[a]	1.90[a]
	(1.50)	(1.54)	(1.57)	(1.69)	(1.61)	(1.56)	(1.52)	(1.35)	(1.54)
SEm±	0.02	0.02	0.01	0.01	0.02	0.03	0.02	0.03	0.01
CD (p=0.05)	0.09	0.07	0.04	0.04	0.07	0.09	0.08	0.11	0.05

*Mean of 50 plants. Values in the parentheses are square root transformed values. Values denoted by common letter are statistically on par at 0.05% as per DMRT

1.26 beetles plant^{-1} whereas control module recorded 1.94 beetles plant^{-1}. However, it was documented that the coccinellid beetles recorded in BIPM and IPM modules, IPM and FP modules were found to be on par but significantly different from control module. During seventh week of observation maximum population of coccinellid beetles was observed in BIPM module (1.20 beetles plant^{-1}) followed by IPM module with 1.02 beetles plant^{-1}. Minimal coccinellid beetles plant^{-1}was observed in FP module with 0.84 beetles plant^{-1}whereas control module recorded 1.82 beetles plant^{-1}. However, it was documented that the coccinellid beetles recorded in BIPM and IPM modules, IPM and FP modules were found to be on par but significantly different from control module.During eighth week of observation maximum population of coccinellid beetles was observed in BIPM module (0.94 beetles plant^{-1}) followed by IPM module with 0.76 beetles plant^{-1}. Minimal coccinellid beetles plant^{-1}was observed in FP module with 0.44 beetles plant^{-1}whereas control module recorded 1.34 beetles plant^{-1}. However, it was documented that the coccinellid beetles recorded in BIPM and IPM modules were found to be on par but significantly different from other modules.

The mean population of coccinellid beetles was maximum in BIPM module (1.65 beetles plant^{-1}) followed by IPM module with 1.49 beetles plant^{-1}. Minimal coccinellid beetles plant^{-1-} was observed in FP module with 1.11 beetles plant^{-1} whereas control module recorded 1.90 beetles plant^{-1}. However, it was documented that the coccinellid beetles recorded in BIPM and IPM modules were found to be on par but significantly different from other modules.

3.3. Impact of different test modules on the abundance of green lacewing in pigeonpea eco-system

The results obtained with regard to the abundance of green lacewing (Table 3) has revealed that their population during first week of observation were maximum in BIPM module (1.56 grubs plant^{-1}) followed by IPM module with 1.28 grubs plant^{-1}. Minimal population was recorded in FP module with 0.56 grubs plant^{-1} whereas control module recorded 1.64 grubs plant^{-1}. During second week of observation maximal population of grubs of lacewing were recorded in BIPM module (1.88 grubs plant^{-1}) followed by IPM module with 1.50 grubs plant^{-1}. Minimal population was recorded in FP module with 1.10 grubs plant^{-1} whereas control module recorded 1.96 grubs plant^{-1}. During third week of observation, maximal population of grubs of lacewing were recorded in BIPM module with 2.08 grubs plant^{-1} followed by IPM module with 1.88 grubs plant^{-1}. Minimal population was recorded in FP module with 1.28 grubs plant^{-1} whereas control module recorded 2.12 grubs plant^{-1}. During fourth week of observation, maximal population of grubs of lacewing were recorded in BIPM module (2.24 grubs plant^{-1}) followed by IPM module with 2.10 grubs plant^{-1}. Minimal population was recorded in FP module with 1.36 grubs plant^{-1} whereas control module recorded 2.34 grubs plant^{-1}. However, it was observed that the grub population recorded in BIPM, IPM and control module were found to be on par but significantly different from FP module.

During fifth week of observation, maximal population of grubs of lacewing were recorded in BIPM module (2.00 grubs plant^{-1}) followed by IPM module with 1.80 grubs plant^{-1}. Minimal population was recorded in FP module with 0.90 grubs plant^{-1} whereas control module recorded 2.04 grubs plant^{-1}. During sixth week of observation, maximal population of grubs of lacewing were recorded in BIPM module (1.88 grubs plant^{-1}) followed by IPM module with 1.80 grubs plant^{-1}. Minimal population was recorded in FP module with 0.72 grubs plant^{-1} whereas control module recorded 2.02 grubs plant^{-1}. During seventh week of observation maximal population of grubs of lacewing were recorded in BIPM module (1.60 grubs plant^{-1}) followed by IPM module with 1.32 grubs plant^{-1}. Minimal population was recorded in FP module with 0.52 grubs plant^{-1} whereas control module recorded 1.64 grubs plant^{-1}. During eighth week of observation, maximal population of grubs of lacewing were recorded in BIPM module (1.32 grubs plant^{-1}) followed by IPM module with 1.12 grubs plant^{-1}. Minimal population was recorded in FP module with 0.20 grubs plant^{-1} whereas control module recorded 1.48 grubs plant^{-1}. However, it was revealed that the grub population recorded in BIPM and control module, BIPM and IPM were found to be on par but significantly different from FP module.

The mean observation on population of grubs of lace wing were maximum in BIPM module (1.82 grubs plant^{-1}) followed by IPM module with 1.60 grubs plant^{-1}. Minimal population was recorded in FP module with 0.83 grubs plant^{-1} whereas control module recorded 1.90 grubs plant^{-1}. However, it was observed that the grub population recorded in BIPM and control module were found to be on par but significantly different from other modules.

3.4. Impact of different test modules on the abundance of spiders in pigeonpea eco-system

The results obtained with respect to the abundance of coccinellid beetles (Table 4) has revealed that their population during first week of observation were maximum in BIPM module with 1.30 plant^{-1} followed by IPM module (1.20 spiders plant^{-1}). Minimal spider population was recorded in FP module with 0.58 plant^{-1} whereas control module recorded 1.50 spiders plant^{-1}. During second week of observation, maximal population of spiders were recorded in BIPM module (1.64 spiders plant^{-1}) followed by IPM module with 1.54 spiders plant^{-1}. Minimal population was recorded in FP module with 1.04 spiders plant^{-1} whereas control module recorded 1.80 spiders plant^{-1}. During third

Table 3: Impact of different test modules on the abundance of green lacewing in pigeonpea eco-system during *kharif* 2007-08

Module	Period of observations*								
	Week I	Week II	Week III	Week IV	Week V	Week VI	Week VII	Week VIII	Mean
Bio Intensive pest Management (BIPM)	1.56[a] (1.43)	1.88[a] (1.54)	2.08[a] (1.60)	2.24[a] (1.65)	2.00[a] (1.58)	1.88[ab] (1.54)	1.60[a] (1.44)	1.32[ab] (1.34)	1.82[a] (1.52)
Integrated Pest Management (IPM)	1.28[b] (1.33)	1.50[b] (1.41)	1.88[b] (1.54)	2.10[a] (1.61)	1.80[b] (1.51)	1.80[b] (1.51)	1.32[a] (1.34)	1.12[b] (1.27)	1.60[b] (1.44)
Farmers Practice (FP)	0.56[c] (1.02)	1.10[c] (1.26)	1.28[c] (1.33)	1.36[b] (1.36)	0.90[c] (1.18)	0.72[c] (1.10)	0.52[b] (1.00)	0.20[c] (0.83)	0.83[c] (1.14)
Control	1.64[a] (1.45)	1.96[a] (1.56)	2.12[a] (1.61)	2.34[a] (1.68)	2.04[a] (1.59)	2.02[a] (1.58)	1.64[a] (1.45)	1.48[a] (1.40)	1.90[a] (1.54)
SEm±	0.02	0.02	0.01	0.03	0.01	0.01	0.04	0.02	0.01
CD (p=0.05)	0.06	0.07	0.05	0.09	0.06	0.05	0.12	0.08	0.05

*Mean of 50 plants. Values in the parentheses are square root transformed values. Values denoted by common letter are statistically on par at 0.05% as per DMRT

Table 4: Impact of different test modules on the abundance of spiders in pigeonpea eco-system during *kharif* 2007-08

Module	Period of observations*								
	Week I	Week II	Week III	Week IV	Week V	Week VI	Week VII	Week VIII	Mean
Bio Intensive pest Management (BIPM)	1.30[b] (1.33)	1.64[ab] (1.46)	2.08[a] (1.60)	2.20[ab] (1.64)	2.14[a] (1.62)	2.04[a] (1.59)	1.48[ab] (1.40)	1.40[a] (1.37)	1.78[a] (1.50)
Integrated Pest Management (IPM)	1.20[b] (1.30)	1.54[b] (1.42)	1.80[b] (1.51)	2.04[b] (1.59)	1.90[b] (1.54)	1.58[b] (1.44)	1.36[b] (1.36)	1.10[a] (1.26)	1.56[b] (1.43)
Farmers Practice (FP)	0.58[c] (1.03)	1.04[c] (1.23)	1.32[c] (1.34)	1.50[c] (1.41)	1.42[c] (1.38)	1.04[c] (1.24)	0.60[c] (1.04)	0.26[b] (0.87)	0.97[c] (1.19)
Control	1.50[a] (1.41)	1.80[a] (1.51)	2.08[a] (1.60)	2.36[a] (1.69)	2.32[a] (1.67)	2.06[a] (1.59)	1.62[a] (1.45)	1.36[a] (1.36)	1.88[a] (1.54)
SEm±	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.04	0.01
CD (p=0.05)	0.07	0.07	0.05	0.06	0.05	0.06	0.07	0.12	0.04

*Mean of 50 plants. Values in the parentheses are square root transformed values. Values denoted by common letter are statistically on par at 0.05% as per DMRT

week of observation, maximal population of spiders were recorded in BIPM module with 2.08 spiders plant^{-1} followed by IPM module (1.80 spiders plant^{-1}). Minimal population was recorded in FP module with 1.32 spiders plant^{-1} whereas control module recorded 2.08 spiders plant^{-1}. During fourth week of observation, maximal population of spiders were recorded in BIPM module (2.20 spiders plant^{-1}) followed by IPM module with 2.04 spiders plant^{-1}. Minimal population was recorded in FP module with 1.50 spiders plant^{-1} whereas control module recorded 2.36 spiders plant^{-1}. However, it was revealed that the spider population recorded in BIPM and control module, BIPM and IPM module were found to be on par but significantly different from FP module.

During fifth week of observation, maximal population of spiders were recorded in BIPM module (2.14 spiders plant^{-1}) followed by IPM module with 1.90 spiders plant^{-1}. Minimal population was recorded in FP module with 1.42 spiders plant^{-1} whereas control module recorded 2.32 spiders plant^{-1}. During sixth week of observation, maximal population of spiders were recorded in BIPM module with 2.04 spiders plant^{-1} followed by IPM module (1.58 spiders plant^{-1}). Minimal population was recorded in FP module with 1.04 spiders plant^{-1} whereas control module recorded 2.06 spiders plant^{-1}. During seventh week of observation, maximal population of spiders were recorded in BIPM module (1.48 spiders plant^{-1}) followed by IPM module with 1.36 spiders plant^{-1}. Minimal population was recorded in FP module with 0.60 spiders plant^{-1} whereas control module recorded 1.62 spiders plant^{-1}. During eighth week of observation, maximal population of spiders were recorded in BIPM module (1.40 spiders plant^{-1}) followed by IPM module with 1.10 spiders plant^{-1}. Minimal population was recorded in FP module with 0.26 spiders plant^{-1} whereas control module recorded 1.36 spiders plant^{-1}. However, it was observed that the spider population recorded in BIPM, IPM and control module were found to be on par but significantly different from FP module.

The mean observation on population of spiders were maximum in BIPM module (1.78 spiders plant^{-1}) followed by IPM module with 1.56 spiders plant^{-1}. Minimal population was recorded in FP module with 0.97 spiders plant^{-1} whereas control module recorded 1.88 spiders plant^{-1}. However, it was observed that the spider population recorded in BIPM and control module were found to be on par but significantly different from IPM and FP module. However, with regard to conservation of natural enemies, BIPM has shown its supremacy by being significantly different from IPM and FP module. The trend was almost similar from first week of observation to eighth week of observation with slight variations here and there indicating the environmental friendly plant protection measures that were incorporated in BIPM.

The results were supported by Sisgsgaard and Ersboll (1999) who noted that insecticidal application had a strong adverse effect on natural enemies, generalist predators like anthisids and *Chrysoperla inornatum.* Similar results were obtained by Srinivasa Rao and Dharma Reddy (2003) who reported more activity of spiders and coccinellids in IPM modules. The results obtained on extent of damage (Table 5) had shown that minimum pod damage, grain damage and seed damage per cent was recorded in FP module which was found to be on par with IPM module. Maximum pod damage per cent was recorded in BIPM module but significantly different from control module whereas regarding per cent seed mass loss, the minimum was recorded in FP module which was on par with BIPM module followed by IPM module but significantly different from control module. The results are in accordance with Arvind Reddy (2001), Benagi et al. (2004), Samiayyan and Srinivasan (2005) who reported that IPM module recorded lowest pod damage, seed damage and grain damage compared to non IPM plots.

Perusal of the results obtained regarding yield attributes (Table 6) in different test modules had revealed that, all were found to be on par recording 1242 kg ha^{-1}, 1205 kg ha^{-1}, 1202 kg ha^{-1} in IPM, FP and BIPM modules whereas control module recorded 1006 kg ha^{-1}. The present results are supported by Singh et al.(2003); Siddegowda et al. (2002) who reported higher yields in IPM plots compared to control. Similar results were obtained by Srinivasa Rao and Dharma Reddy (2003) who documented that IPM module (*Ha*NPV-endo-NSKE) was effective in reducing grain damage and recorded higher yields in pigeonpea.

The perusal of the results had showed that per cent yield gain was maximum in IPM module (23.45) followed by FP module (19.78%) and BIPM module with 19.48% when compared with control. The results regarding per cent avoidable yield loss had revealed that by adopting IPM module 19.00 per cent yield loss can be avoided in control module followed by 3.22 per cent in BIPM module and 2.97 per cent in FP module. By adopting IPM module 236 kg ha^{-1} additional yield was achieved over control followed by FP module (199 kg ha^{-1}) and BIPM module wherein 196 kg additional yield was achieved per hectare over control.

Among the different modules tested, BIPM module recorded maximum cost benefit ratio of 1:1.20 followed by IPM module (1:1.18). Least cost benefit ratio was recorded by FP module (1:1.02) compared to control module (Table 7). Singh et al. (2003) reported maximum cost benefit ratio of 1:3.06 in IPM plots compared to control. Joshi and Srivastava (2006) reported highest C:B ratio of 1:3.22 and 1:3.35 in module-II during both the years.

Table 5: Impact of different test modules on the extent of damage by *H. armigera* in pigeonpea

Module	Extent of Damage*			
	Pod damage (%)	Grain damage (%)	Seed damage (%)	Seed mass loss (%)
Bio Intensive Pest Management (BIPM)	5.86^{b} (13.97)	8.61^{b} (17.03)	6.46^{b} (14.63)	5.63^{b} (13.70)
Integrated Pest Management (IPM)	4.29^{ab} (11.85)	5.00^{a} (12.84)	5.19^{ab} (13.13)	5.08^{b} (13.02)
Farmers Practice (FP)	3.16^{a} (10.14)	4.70^{a} (12.49)	3.62^{a} (10.87)	3.92^{a} (11.42)
Control	21.20^{c} (27.31)	25.37^{c} (30.18)	19.31^{c} (25.93)	13.05^{c} (21.15)
SEm±	0.88	0.81	0.82	0.39
CD (p=0.05)	2.71	2.51	2.52	1.21

*Mean of 100 pods grains^{-1} seeds^{-1}. Values in the parentheses are arc sine transformed values. Values denoted by common letter are statistically on par at 0.05% as per DMRT.

Table 6: Impact of different test modules on the yield attributes in pigeonpea ecosystem

Module	Yield attributes			
	A	B	C	D
Bio Intensive Pest Management (BIPM)	1202	19.48	3.22	196
Integrated Pest Management (IPM)	1242	23.45	-	236
Farmers Practice (FP)	1205	19.78	2.97	199
Control	1006	-	19.00	-
SEm±	52.9	-	-	-
CD (p=0.05)	163.05	-	-	-

A=Grain yield (kg ha^{-1}); B=Yield gain (%); C=Avoidable yield loss (%); D=Additional yield over control (kg ha^{-1});

Table 7: Net returns and cost: benefit ratio in different modules tested for management of *H. armigera* in pigeonpea

Module	A	B	C	D
Bio Intensive Pest Management (BIPM)	27440.00	875.00	26565.00	1:1.20
Integrated Pest Management (IPM)	27324.00	1115.00	26209.00	1:1.18
Farmers Practice (FP)	26510.00	3867.00	22643.00	1:1.02
Control	22132.00	-	22132.00	-

A=Gross Monetary returns (₹ ha^{-1}); B=Total cost of application (₹ ha^{-1}); C=Net returns (₹ ha^{-1}) ; D=Cost:benefit ratio;

4. Conclusion

Though extent of damage caused by *H. armigera* in BIPM module is found to be on par with IPM module but significantly different from farmers practice module and control module, BIPM which had eco-friendly inputs as the main components, fared well in terms of better net returns as well as effective conservation of natural enemies in the pigeonpea eco-system.

5. Referances

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