Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(6): 256-265

Received: 08-09-2018
Accepted: 10-10-2018

Nitesh Kumar Maru
Department of Entomology, Naini Institute of Agriculture Sam Higgin bottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh, India

Ashwani Kumar
Department of Entomology, Naini Institute of Agriculture Sam Higgin bottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh, India

Correspondence
Nitesh Kumar Maru
Department of Entomology, Naini Institute of Agriculture Sam Higgin bottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh, India

Comparison of bio-rational and bio-intensive IPM modules for safe pesticide residue and management of brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee with economics

Nitesh Kumar Maru and Ashwani Kumar

Abstract
A field study was undertaken in *Rabi* 2017, at the Central Research Farm and dept. of horticulture farm, SHUATS Allahabad, with the objectives to assess the bio-efficacy and economics of bio-rational and bio-intensive IPM modules against shoot and fruit borer, and to analyze the insecticide residues in edible fruits of brinjal. Seven modules (3 Bio Rational, 1 Farmers Practice and 3 Bio intensive) were evaluated against shoot and fruit borer, (*Leucinodes orbonalis*). In experiment 1, Bio rational IPM Module T2 comprising of Seedling treatment with Chlorpyrifos, coriander as a border crop, and 1 spray each of Deltamethrin 1%+ Triazophos, Cyantraniliprole and Spinosad, at 30, 45 and 60 DAT was found to have least % shoot/fruit damage. Bio rational IPM Module T1 [BCR 1 : 3.89] (comprising of Seedling treatment with Chlorpyrifos and 1 spray each of Chlorantraniliprole, Spinetoram and Emamectin Benzoate at 30, 45 and 60 DAT) found most advantageous if produce was sold at equal price. In experiment 2, Bio intensive IPM Module T2 [BCR 1: 5.18] (Installations of pheromone trap, release of egg parasitoid *Trichogramma chilonis*, 2 spray *Beauveria bassiana* at 30 and 45 DAT, 1 spray of Azadirachtin at 60 DAT) was found effective and economic against the pest; it is also assessed best among all the modules if farmers get higher price of produce. All the modules were found safe from consumer's point of view if fruits are harvested at 10 days after application of insecticides.

Keywords: IPM modules, insecticide residue analysis, *Leucinodes orbonalis*, Cyantraniliprole, Spinetoram

1. Introduction
Brinjal (*Solanum melongena* Linnaeus) also known as eggplant is referred as "King of vegetables", originated from India and now grown as a vegetable throughout the tropical, sub-tropical and warm temperate areas of the world. It is one of the three most important vegetable species cultivated in South Asian region (Bangladesh, India, Nepal, and Sri Lanka) accounting for almost 50% of world's vegetable growing area under its cultivation (Alam *et al.*, 2003) [1]. As per FAOSTAT (2016) [10] data, China is the top producer (61% of world output) while India ranks second (25%) in brinjal production.

In India, It is grown in almost all states, with an area of 679.4 thousand hectares under cultivation and production of 12438.7 thousand metric tons (Anonymous, 2015) [3]. The major brinjal growing states in India are Andhra Pradesh, Karnataka, West Bengal, Maharashtra, Orissa, Madhya Pradesh, Bihar, Gujarat and Chhattisgarh.

A substantial proportion of brinjal yield is lost due to biotic and abiotic stresses (Singh *et al.* 2016) [38]. Arthropod biodiversity in the brinjal field showed that the brinjal shoot and fruit borer was the major and serious insect pest of brinjal crop. (Kumar *et al*, 2017) [20].

Larvae of pest bore into tender shoots making zigzag feeding tunnels in fruits, which are clogged with frass that make fruits unfit for consumption and marketing.

The apparent yield loss due to BFSB varies from 20-90 per cent in various parts of the country (Raju *et al.*, 2007) [32], 85–90 per cent has been reported (Patnaik, 2000; Misra, 2008 and Jagginavar *et al.*, 2009) [26, 21, 14]. It may cause 100 per cent damage if no control measures are applied (Rahman 2007) [29]. It is estimated that the economic injury level equals to 6 per cent infestation of shoot and fruit in India (Alam *et al.*, 2003) [1].

The inadequate information about the special feeding behaviour of BSFB has led to its management challenging and difficult (Vageesh babu *el al.*, 2014) [41]. The internal feeding behaviour of *Leucinodes orbonalis* Guenee reduces the effectiveness of insecticides used against them. To combat this problem, farmers tend to spray insecticides twice a week which leads to development of resistance in the target insect. The bioaccumulation, bio magnifications and disturbances in the ecological balance are the other problems associated with the excess use of insecticides in brinjal (Shanmugam *et al*., 2015) [36].

The research and development activities to control BSFB have largely been confined to screening pesticides to select the most effective chemical and determining the frequency of their use. But after the advent of IPM concept other non-chemical measures *viz*. host plant resistance and biological, cultural, physical and mechanical control are constantly evaluated and calibrated on different seasons, in various locations all over the world, for their incorporation to make Ideal IPM Module, which can be recommended to the farming community of the specific locality.

There have been some outstanding developments in practical application of IPM in many developed countries where the ultimate goal is to decrease overreliance on conventional insecticides. As far as control of *Leucinodes orbonalis* is concerned, it is very essential to develop cost effective strategies, without disrupting the agro ecosystem. Also due to export potential of brinjal fruit, it is imperative to include alternate plant protection measures towards minimizing the use of insecticides. Therefore, it is enviable to evaluate different management modules including microbial, cultural, mechanical and new generation insecticide molecules (with circular use of different mode of action insecticides) for the management of *Leucinodes orbonalis* Guenee in brinjal. In this sequence, scattered information on insecticidal efficacy of some newer molecule and IPM modules are there on record in different parts of the country.

However, no such studies have been taken in Allahabad region; also, available modules are reasonable to be assessed to derive a best-fit module, which could be proved economically viable, environmentally safe and socially acceptable. Taking all the above facts in to consideration, the present studies were undertaken in Allahabad conditions.

2. Materials and Methods

The study was carried out at the research farm of the Department of Entomology, Naini Agricultural Institute, SHUATS, Allahabad during *rabi* season of 2017.

A Variety of Round Brinjal '*Kanshi Sandesh*' developed by IIVR Varanasi has been chosen for the field experiment. Seeds were sown in nursery of Department of Horticulture in the first week of August and the seedlings were raised on Disposable PVC Cups. Thirty days old seedlings were transplanted during the first week of September and the standard agronomic package of practices and irrigation schedule, excluding plant protection treatment were followed to raise and maintain a healthy crop.

In this experiment, plant spacing of 60 x 50 cm^2 was kept, on plot size 3x2 m^2 areas, with 3 replications. Bio-rational IPM module (Experiment no-1) and Bio- intensive IPM module (Experiment no-2) were transplanted at two separate locations isolated with a distance of 680 meters to avoid any undesirable masking/super shedding effect of one module over other. Infestation of BSFB on shoot and fruit, during the experimental period *i.e*. 31st standard week (First week of August, 2017) to 52nd standard week (Last week of December, 2017) was recorded on these experimental plots.

Three bio-rational IPM modules in experiment number 1 and three bio- intensive IPM modules in experiment number 2, were compared with a farmers practiced module and a non-treated control. The treatments in each module were made keeping in view the recommendations of Insecticide Resistance Action Committee (IRAC) with an aim to formulate a complete package for control of BSFB, which must be economical, socially acceptable and safe to the environment. The doses in farmers practice module were kept a little higher side to mimic indiscriminate use by a layman farmer. Plain water was sprayed in untreated control. The details of components of various modules are as mentioned in table 1, 2 & 3

Table 1: Experiment 1. Bio Rational Treatments (4 Replications)

T 0	Control
T1	Root dip + Chemicals
T2	Root dip + Chemicals+ Cultural
T3	Root dip + Chemicals + Cultural+ Mechanical
T4	Chemicals (Farmers Practice Module)
Experiment 2. Bio intentional Treatments (5 Replications)	
T0	Control
T1	Mechanical + Parasitotid level 1 + Bacterial pathogen + Botanical
T2	Mechanical + Parasitotid level 2 + Fungal pathogen + Botanical
T3	Mechanical + Parasitotid level 3 + Botanicals + Botanical

Table 2: Treatments in Experiment - 1(Bio-Rational Modules)

T-1	1	Seedling treatment - Chlorpyrifos 20% EC @1 ml/lit for 3 hours before transplanting.
	2	One spray of Chlorantraniliprole 18.5 % SC @ 40 g a.i. ha^{-1}30 DAT (200ml/ha)
	3	One spray Spinetoram 11.7% SC @ 21 g a.i. ha^{-1}45 DAT (180 ml/ha)
	4	One spray of Emamectin Benzoate 5 SG @10 g a.i. ha^{-1}60 DAT (200 g/ha)
T-2	1	Seedling treatment - Chlorpyrifos 20% EC @1 ml/lit for 3 hours before transplanting.
	2	Transplanting two rows of coriander as a border crop
	3	One spray of Deltamethrin 1%+ Triazophos 35% EC @ 360(10+350) ml a.i. ha^{-1} at 30 DAT (1000 ml/ha)
	4	One spray of Cyantraniliprole 10.26% OD@ 60 ml a.i. ha^{-1}45 DAT (600ml/ha)
	5	One spray of Spinosad 45%SC @ 73 g a.i. ha^{-1}60 DAT (160 ml/ha)
T-3	1	Seedling treatment - Chlorpyrifos 20% EC @1 ml/lit for 3 hours before transplanting.
	2	Transplanting two rows of coriander as a border crop
	3	Mechanical clipping of infested terminal shoots at weekly interval
	4	one spray of Lambda Cyhalothrin 5% CS @15 ml a.i. ha^{-1} at 30 DAT (300ml/ha)
	5	One spray of Indoxacarb 14.5 SC @ 50-60 ml a.i. ha^{-1}45 DAT (333-400ml/ha)
	6	One spray of Flubendiamide 39.35% SC @48 a.i. ha^{-1} at 60 DAT (100 ml/ha)
		TREATMENTS FARMERS PRACTICE MODULE

T4	1	One spray of Dimethoate 30% EC@ 300 ml a.i. ha^{-1} at 30 DAT (990ml/ha) {Against 200 ml a.i. ha^{-1} and 660 ml/ha }
	2	One spray of Fenvalerate 20% EC @ 150 ml a.i. ha^{-1} at 45 DAT (750ml/ha) {Against 100 ml a.i. ha^{-1} & 500 ml/ha}
	3	Fipronil 5% SC @ 50 ml a.i. ha^{-1}60 DAT (1000 mi/ha)
T-0		Un Treated Control

Table 3: Treatments In Experiment - 2. (Bio- Intensive Ipm Modules)

T -0	1	Control
T-1	2	Installations of Pheromone trap @ 5 traps/acre for monitoring the population of *L. orbonalis*.
	3	Six release of egg parasitoid, *Trichogramma chilonis*@ 0.5 Lakh/ha against *L. orbonalis*, initiated with flowering and subsequent at 10 days intervals.
	4	TWO spray of *Bacillus thuringiensis* var. kurstaki 17600 IU/mg 3.5%w/w @ 1500 ml/ha at 30 AND 45 days after transplanting
	5	One sprays of Azadirachtin 1% (10000 ppm) @1000 ml/ha at 60 DAT
T-2	1	Installations of pheromone trap @ 5 traps/acre for monitoring the population of *L. orbonalis*.
	2	Six release of egg parasitoid, *Trichogramma chilonis*@ 1 Lakh/ha against *L. orbonalis*, initiated with flowering and subsequent at 10 days intervals.
	3	Two spray of *Beauveria bassiana*1.15% WP(CFU $1x10^8$ per g min.) @ 2000 ml/ha at 30 AND 45 DAT
	4	One sprays of Azadirachtin 1% (10000 ppm) @1000 ml/ha at 60 DAT
T-3	1	Installations of pheromone trap @ 5 traps/acre for monitoring the population of *L. orbonalis*.
	2	Six release of egg parasitoid, *Trichogramma chilonis*@ 1.5 Lakh/ha against *L. orbonalis*, initiated with flowering and subsequent at 10 days intervals.
	3	sprays of Azadirachtin 1% (10000 ppm) @1000 ml/ha at 30 DAT,45 DAT, 60 DAT

Method of recording observation for efficacy of modules

Observations were record on the number of infested shoots in each plot 1 day before spray and 3, 7 and 14 days after spraying on 10 randomly selected/tagged plants. The cumulative per cent shoot damage was worked out using the formula.

$$\%\ \text{Shoot Damage} = \frac{\text{Number of Damaged Shoot}}{\text{Total Number of Shoots}} \times 100$$

Observations were recorded on the number of infested fruits and number of marketable fruits per plot wise from selected/tagged plants. The per cent fruit damage was worked out by using the formula.

$$\%\ \text{fruit Damage} = \frac{\text{Number of Damaged fruit}}{\text{Total Number of Shoots}} \times 100$$

The yield data were obtained by weighing the healthy and damaged fruits in each plot separately (Module wise) during every picking at fortnightly interval from randomly selected and tagged ten plants. The yield of all pickings were computed and expressed in kg per plot from which the yield in quintals per hectare was calculated.

$$\text{Yield in Q/Ha} = \frac{\text{Yield in Module (Kg/Plot)}}{\text{Plot Area in Square Meters}} \times 100$$

The yield data of marketable fruits at different pickings in each modules were recorded separately and subjected to statistical analysis to test the significance of mean yield in different modules by following the procedure given by Panse and Sukhatme (1985) [24]. The per cent infestation of shoot and fruit borer was subjected to the same procedure of Analysis of Variance (ANOVA), so that differential per cent infestation in the treatment could be assessed separately. While comparing the yield from different modules, the per cent increase in yield over control (IYC); was calculated by following the procedure given by Pradhan (1969) [28].

$$\text{IYC} = \frac{\text{Yield in Modules} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

The data obtained were analysed statistically after using appropriate transformation. The percentage data were processed under Arcsine transformation before statistical analysis. Using this formulae: $Y = \text{arcsine} \sqrt{p} = \sin^{-1} \sqrt{p}$ (with the help of Microsoft excel). This transformed data was then analysed by the method of analysis of variance as described by Gomez and Gomez (1984) [12]. The “F” test was used at 5 per cent level of significance. Critical difference (CD) values were analysed at 5 per cent level of significance.

Cost Benefit Ratio of Modules

Economic analysis measuring the productivity, costing analysis, gross and net returns, and benefit-cost ratios per unit of land for Brinjal in various modules was done.

$$\text{BCR} = \frac{\text{Net returns \{Gross profit} - \text{(total cost+ labour income)\}}}{\text{Cost of treatment (Variable cost+ marketing cost)}}$$

Insecticide Residues In Edible Fruits

The green edible fruits were collected from module T1, T2, T3 and T4 (of experiment no-1) after 10 days of spraying, as it is harvested and then sent to APEDA (agricultural and processed food products export development authority) recognized Laboratories for analysis of any trace of insecticide residues in edible parts.

3. Results and Discussion

The study has been designated to evaluate a suitable IPM Module to suppress the brinjal shoot and fruit borer damage with combination of various bio rational and bio intensive treatments in three sprays. It’s noteworthy that the treatments in each module were made keeping in view the recommendations of Insecticide Resistance Action Committee (IRAC) with an aim to formulate a complete package for control of BSFB, which must be Economical, Socially Acceptable and Safe to the Environment. Efficacy of IPM Modules were determined in terms of per cent shoot damage on number basis, per cent fruit damage on number basis, Percent Avoidable Losses and Increase of yield over control. The results obtained during the present investigation are depicted and discussed here under.

3.1 Shoot infestation

*In Experiment-1,*The efficacy of bio-rational and *farmers practice* modules against shoot and fruit borer, *L. Orbonalis* in brinjal crop revealed that all modules were significantly superior over control in reducing the percent shoot infestation. The Pooled data of 1st and 2nd spray mean of shoot infestation revealed*,* that *among* all the modules lowest percent shoot infestation of *L. Orbonalis* was recorded in T2 (7.71%) followed by T3 (10.125%) which was at par with T1 (10.135%). Farmers practice modules T4 was least effective. Highest shoot infestation was recorded in control T0 (28.475%). The values in parenthesis were arc sign transformation value. (Table 4*; Graph 1*)

H*owever in Experiment -2,* the efficacy of Bio-Intensive modules against *Leucinodes orbonalis* on brinjal *crop revealed that all the modules* were significantly superior over control in reducing the percent shoot infestation.

The Pooled data of 1st and 2nd spray mean of shoot infestation revealed that *among* all the modules lowest percent infestation of *L. Orbonalis* was recorded in T3 (15.148%) followed by T2 (15.836%) and T1 (15.874%). Highest shoot infestation was recorded in control T0 (28.776%). The values in parenthesis were arc sign transformation value. (Table 5*; Graph 2*)

The present findings could not be compared as such with the results of other workers due to difference in treatment combination. However, in experiment number 1 (Bio-rational and Farmers Practice Modules) the findings of few workers could be compared with the results of present investigation after 30 days *viz.* Bhushan *et al.* (2011) [5], who revealed that minimum shoot and fruit damage (9.32 and 14.83 per cent, respectively) was observed in module having shoot clipping with alternate spraying of Multineem (1500 ppm) and Triazophos (35%) + Deltamethrin (1%); Das (2015) [7] who found that IPM module consisting of removal and destruction of infected shoots and fruits and alternate spraying of Triazophos 40 EC @ 1250 ml/ha and neem oil @ 2.5 lit/ha at 10 days interval to be the most effective and economical among three modules assessed for management of shoot and fruit borer of brinjal; and Raina *et al.* (2016) [30] who proved Deltamethrin as most effective in reducing shoot damage (60.40%) and fruit damage, on number basis (88.87%) and weight basis (88.89%) over control and advocated that it may be incorporated in IPM practices against brinjal shoot and fruit borer.

The bio rational module T2 was followed by T1 (Seedling Dip and 1 spray of Chlorantraniliprole at 30 DAT); which is in agreement with Misra (2008) [21], Rajavel *et al.* (2013) [31], Kameshwaran & Kumar (2015) [16], and Niranjana *et al.* (2017) [22] who purported Chlorantraniliprole 18.5% SC to be effective in reducing the shoot and fruit borer infestation remarkably better.

During this period (*i.e.* 30 DAT) in experiment 2 (Bio-Intensive module), T3 (Pheromone trap, *Trichogramma chilonis,* and 3 sprays of Azadirachtin at 30, 45 and 60 DAT) proved to be an effective module against pest (*Leucinodes orbonalis*) with minimum shoot infestation and remained best among all the modules. The present findings are in agreement with the results of Singh *et al.* (2016) [38] who reported that the Bio-pesticide NSKE 5 per cent was found most effective followed by *Bacillus thuringensis, Verticellium lecanii* and *Beauveria bassiana*.; and Khajuria *et al.* (2017) [17] who recommended installation of pheromone traps and spraying of Neem oil for effective management of brinjal fruit and shoot borer; Sahu *et al.* (2017) [34] who found similar results as NSKE was better followed by *Beauria bassiana* and *Bacillus thuringiensis.*

After second application of treatments *i.e.* 45 DAT, In experiment number 1 (Bio-rational and Farmers Practice Modules), Module T2, (Seedling Dip, Border crop and 1 spray of Deltamethrin + Triazophos and Cyantraniliprole each at 30 and 45 DAT) remained best among all the modules. The present findings are in agreement with Kodandaram *et al.* (2015) [19] who indicated that Cyantraniliprole is highly effective among different diamide insecticides.

T2 was followed by T3 (Seedling Dip, Border crop, Mechanical clipping of infested terminal shoots, 1spray of Lambda Cyhalothrin and Indoxacarb each at 30 and 45 DAT). The findings can be supported by Dwivedi *et al.* (2014) [8] who found Indoxacarb to be effective against BSFB; Pawar *et al.* (2009) [27] who suggested use of mechanical clipping of infested shoots at weekly interval significantly reduced *Leucinodes orbonalis* infestation. Khorsheduzzaman *et al.* (1997) [18], Satpathy *et al.* (2011) [35]and Sujayanand *et al.* (2015) [39] who found that intercropping/border cropping coriander with Brinjal might be an effective IPM component against *L. orbonalis* in reducing both fruit infestation and amount of insecticide used by farmers.

During this period (*i.e.* 45 DAT) in experiment 2 (Bio-Intensive module), T2 (Pheromone trap, *Trichogramma chilonis,* 2 sprays of *Beauveria bassiana,* 1 spray of Azadirachtin) remained best among all the modules followed by T3 (Pheromone trap, *Trichogramma chilonis,* 3 sprays of Azadirachtin at 30, 45 and 60 DAT) which proved to be an effective insecticide against pest (*Leucinodes orbonalis*) with less shoot infestation and remained better than T1 and control. The present findings are in agreement with the results of Ghosh and Senapati (2009) [11] who revealed that avermectin (Vertimec 1.9 EC; 0.5 ml/l) was the most effective in suppressing dead heart caused by the pest *Leucinodes orbonalis*, closely followed by Beauveria bassiana (Biorin 10^7 conidia/ml; 1 ml/l) and Bacillus thuringiensis Berliner (Biolep 5-9x10^7 spores/ml; 1 g/l).

3.2 Fruit infestation

The data on the mean percent fruit infestation of brinjal shoot and fruit borer revealed that all the modules were superior over control and in experiment number -1, bio-rational modules were superior then farmers practice modules.

Elaborately in Experiment number -1; The Pooled data of 2nd and 3rd spray mean of fruit infestation revealed that all the modules were significantly superior over control. Bio rational modules performed better followed by farmers practice modules. Among all the modules lowest percent infestation of shoot and fruit borer was recorded in T2 (10.655%) which was at par with T1 (11.780%). The next best module T3 (15.675%) was at par with T4 (18.305%). Highest fruit infestation was recorded in T0 (43.185%). The values in parenthesis were arc sign transformation value. (Table 6; Graph 3)

H*owever in Experiment -2,* The Pooled data of 2nd and 3rd spray mean of fruit infestation revealed that all the Bio Intensive modules were significantly superior over control. Among all the modules lowest percent infestation of shoot and fruit borer was recorded in T2 (20.890%) which was at par with T3 (21.644%) and T1 (25.118%) which was least effective in reducing % infestation. Highest fruit infestation was recorded in T0 (43.188%). The values in parenthesis were arc sign transformation value. (Table 7, Graph 4)

The present findings could not be compared as such with the results of other workers due to difference in treatment combination. However, in experiment number 1 (Bio-rational and Farmers Practice Modules) bio rational IPM modules proved to be an effective insecticide module against (*Leucinodes orbonalis*) with minimum fruit infestation as compared to bio intensive modules. Module T2, (Seedling Dip, Border crop and 1 spray of Deltamethrin + Triazophos, Cyantraniliprole and Spinosad each at 30, 45 and 60 DAT) remained best among all the modules. The present findings are in agreement with Adiroubane and Raghuraman (2008) [2] who recorded Maximum per cent reduction of fruit damage in Spinosad; Kalawate and Dethe (2012) [15] who found Spinosad to be the most effective against BSFB as compared to emamectin benzoate and cypermethrin; Singh and Sachan (2015) [37] who reported Application of spinosad to be most effective treatment in reducing the shoot and fruit damage at all observational interval; Yousafi *et al. (2016)* [43] who indicated that Spinosad was more effective in controlling BSFB for a longer period of time than Emamectin benzoate; and Bhagwan and Kumar (2017) [4] who found Spinosad to be effective in reducing the shoot and fruit damage.

In experiment 2 (Bio-Intensive modules) T2 (Pheromone trap, *Trichogramma chilonis,* 2 sprays of *Beauveria bassiana,* 1 spray of Azadirachtin) remained best among all the modules. The present findings are in agreement with Patel *et al.* (2015) [25] who reported that *Beauveria bassiana* @ 1l/ha was effective as it recorded lower infestation of all recorded pests. This was followed by Metarhizium anisopliae, Verticillium lecanii, Neem soap and Pongamia soap.

3.3 Cost benefit ratio

The data on economics of three application of the 8 different modules (3 bio intensive, 3 bio rational and 1 farmers practice Modules along with the controls) given against BSFB of brinjal are presented in Table 8 and 9, And depicted in Graph 5.

Cost benefit ratio was worked out considering two different market prices for chemical and non-chemical marketable produce. When keeping the equal sellable price @ Rs.850 per quintal, the best and most economical Module in experiment 1 (bio rational and farmer practice module) was T1 (1: 3.89), followed by T2 (1:3.69), T3 (1:3.48), T4 (1: 3.47) sand T0 (1: 1.70).

While keeping the equal sellable price @ Rs.850 per quintal, the best and most economical Module in experiment 2 (bio intensive modules) was T2 (1 : 2.98), followed by T3 (1 : 2.85), T1 (1 : 2.58), and T0 (1 : 1.70). However when calculation of bio intensive module's produce is done @ 1500 per quintal, the best module was T2 (1: 5.18), followed by T3 (1: 5.04), T1 (1: 4.56). Its noteworthy here, that bio intensive modules gave batter returns than bio rational and farmer practice module from CBR point of view. T0 in bio intensive module assessed with lowest CBR even @1500/ quintal.

Thus, looking to the effectiveness and economics of different insecticidal treatments applied against the brinjal shoot and fruit borer, *L. orbonalis*, it can be concluded that T1 from experiment 1 (bio rational and farmer practice module) is best if all the modules were sold at equal price and T2 from experiment 2 (Bio intensive modules) was found effective and economic against the pest if farmers get higher rate of produce.

The literature available on a cost: benefit ratio of IPM modules is limited because the labour charges and market price of brinjal fruits may vary from place to place and year to year, therefore, cost: benefit ratio recorded in present findings could not be compared as such with the cost: benefit ratio calculated by other workers. However, the findings of few workers could be compared with the results of present investigation *viz.* Yadav *et al.* (2017) [42] who revealed that application of Module-V consisting bio-intensive (I) + mechanical + chemical method was found more economical than rest of the treatments, for obtaining high returns with high cost: benefit ratio followed by Module-VI (bio-intensive (II) + Mechanical + chemical); Tamoghna *et al.* (2014) [40] who obtained highest Cost benefit ratio in IPM module (1: 31) followed by bio-rational module (1: 22); Panday *et al.* (2016) [23] who revealed that the IPM program (regime 3) that consisted of cultural, mechanical and chemical components was proved to be an ideal management strategy against eggplant shoot and fruit borer along with a benefit: cost ratio of 3.65 to 4.27.

3.4 Insecticide residues analysis in edible fruits 10 days after spraying

The green edible fruits were collected from module T1, T2, T3 and T4 from experiment 1 (bio rational and farmer practice module) after 10 days of spraying, as it is harvested and then sent to APEDA (agricultural and processed food products export development authority) recognized Laboratories for analysis of any trace of insecticide residues in edible parts.

The green vegetable fruits products from the various chemical modules chosen for study of Insecticide residues analysis were found to contain chemical contaminants at non-traceable quantity or within the maximum accepted limits, according to national regulation. In some samples, the investigated pesticides were not detected.

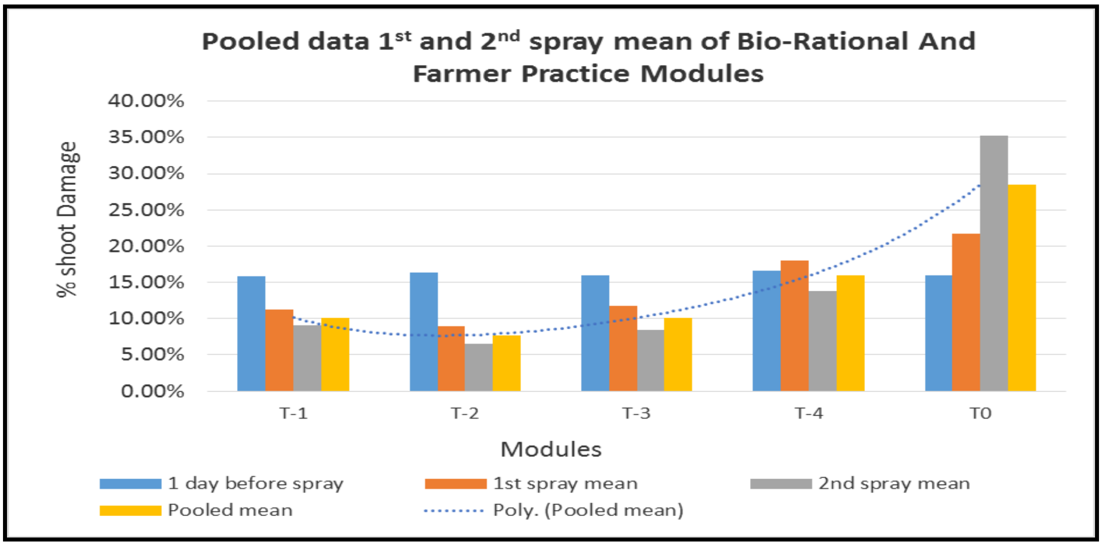
The present findings is in agreement with many researchers *viz*. Iqbal *et al*. (2007) [13] who concluded, that the brinjal fruit was suitable for the consumption of public after three days without posing any hazard to human health, however it's most appropriate at 7 DAS; Chawla *et al.*, (2011) [6] who revealed persistence of Flubendamide in/on brinjal till 3rd and 7th day after the last spray at standard and double dose, respectively; Rao *et al.* (2015) [33] who reported that among the 80 brinjal samples, 46 (56 %) had residues, of these 4 % samples had residues above MRLs. However IPM fields showed substantial reduction sprays which in-turn reflected in lower residues; Faheem *et al.* (2015) [9] who revealed the data on pesticides residues in fruits which shows that most of the samples are contaminated with one or more pesticides including organochlorine, however, this contamination remains within the maximum residues level (MRLs) with few exceptions.

Table 4: Efficacy of Bio-Rational and Farmer's practice module against *Leucinodes orbonalis* on brinjal. (Pooled data of shoot infestation 1st and 2nd spray mean)

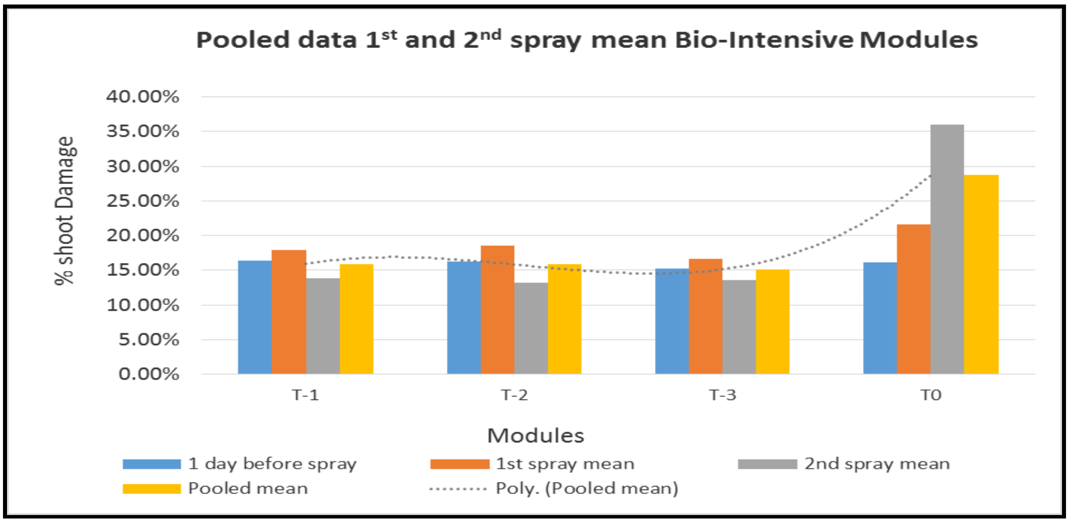
Modules	Shoot infestation			
	1 day before spray	1st spray mean	2nd spray mean	Pooled mean
T-1	15.82 (23.43)	11.20 (19.52)	9.07 (17.46)	10.13 (18.55)
T-2	16.34 (23.85)	8.93 (17.37)	6.49 (14.73)	7.71 (16.11)
T-3	15.92 (23.51)	11.89 (20.17)	8.43 (16.88)	10.12 (18.55)
T-4	16.56 (24.02)	14.51 (22.39)	13.83 (21.82)	15.92 (23.50)
T-0	15.95 (23.54)	21.66 (27.73)	35.30 (36.43)	28.48 (32.25)
Overall mean	16.12	13.64	14.62	14.47
F- test	NS	S	S	S
S. Ed. (±)	0.003	0.44	0.91	0.59
C. D. (P = 0.05)	-	0.97	1.977	1.288

Table 5: Efficacy of Bio-Intensive module against *Leucinodes orbonalis* on brinjal. (Pooled data of shoot infestation 1st and 2nd spray mean)

Modules	Shoot infestation			
	1 day before spray	1st spray mean	2nd spray mean	Pooled mean
T-1	16.33 (23.83)	17.95 (25.04)	13.80 (21.80)	15.87 (23.46)
T-2	16.24 (23.77)	18.52 (25.47)	13.16 (21.23)	15.84 (23.44)
T-3	15.25 (22.98)	16.70 (24.12)	13.60 (21.62)	15.15 (22.89)
T-0	16.12 (23.67)	22.99 (28.64)	35.96 (36.73)	28.78 (32.39)
Overall mean	15.98	19.04	19.13	18.91
F- test	NS	S	S	S
S. Ed. (±)	0.40	0.74	1.70	0.83
C. D. (P = 0.05)	-	1.60	3.695	1.805



Graph 1: Efficacy of Bio-Rational and Farmers practice modules against *Leucinodes orbonalis* on brinjal. (Pooled data of shoot infestation 1st and 2nd spray)



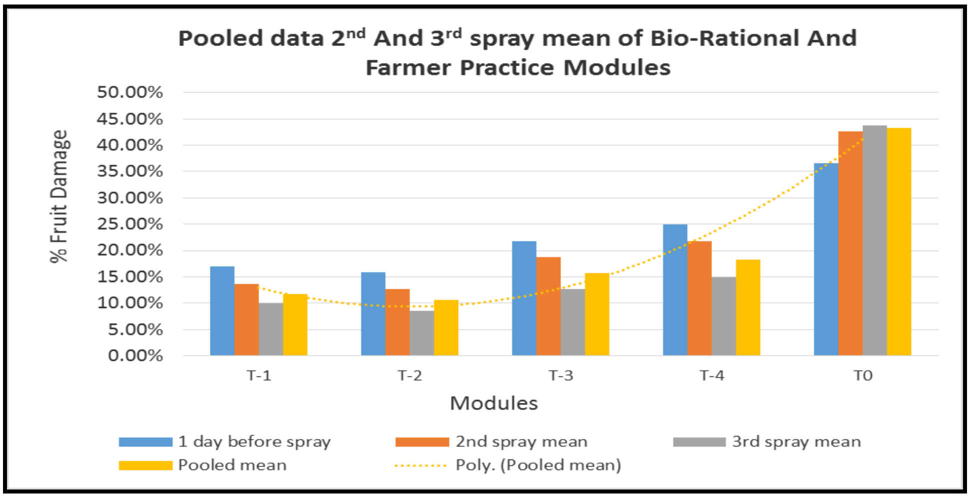
Graph 2: Efficacy of Bio Intensive modules against *Leucinodes orbonalis* on brinjal. (Pooled data of shoot infestation 1st and 2nd spray)

Table 6: Efficacy of Bio-Rational and Farmers Practice Module against *Leucinodes orbonalis* on brinjal. (Pooled data of fruit infestation 2nd and 3rd spray)

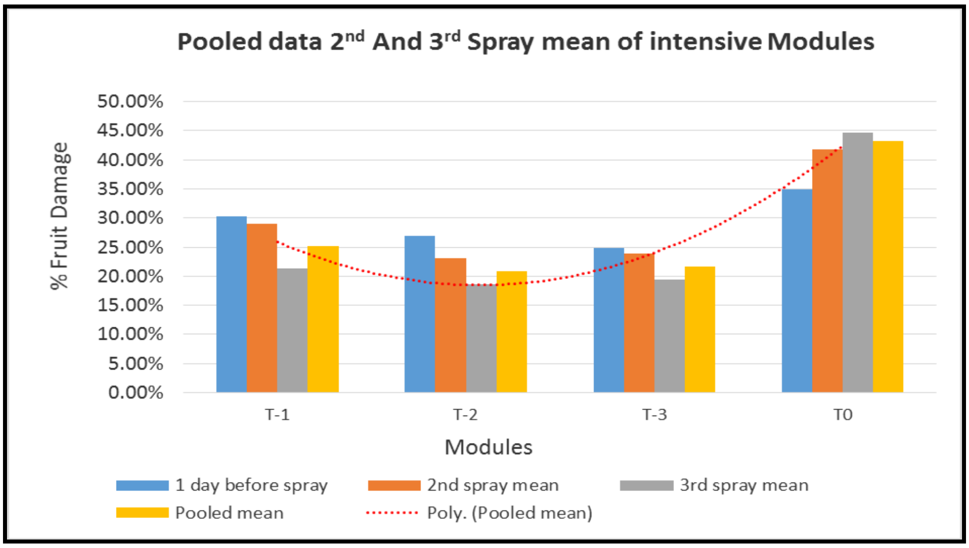
Modules	Fruit infestation			
	1 day before 2nd spray	2nd spray mean	3rd spray mean	Pooled mean
T1	16.98 (24.30)	12.52 (20.70)	9.93 (18.32)	11.78 (20.07)
T2	15.87 (23.48)	11.67 (19.96)	8.59 (17.03)	10.66 (19.06)
T3	21.75 (27.70)	17.63 (24.67)	12.70 (20.87)	15.68 (23.28)
T4	25.00 (29.84)	20.61 (26.98)	14.91 (22.66)	18.31 (25.31)
T5	36.51 (37.14)	44.66 (41.87)	43.75 (41.38)	43.19 (41.04)
Overall mean	23.22	21.42	17.97	19.92
F- test	S	S	S	S
S. Ed. (±)	2.29	2.01	1.46	1.47
C. D.(P = 0.05)	4.976	4.382	3.174	3.207

Table 7: Efficacy of Bio-Intensive Module against *Leucinodes orbonalis* on brinjal. (Pooled data of fruit infestation 2nd and 3rd spray)

Modules	Fruit infestation			
	1 day before 2nd spray	2nd spray mean	3rd spray mean	Pooled mean
T1	30.21 (33.34)	28.96 (32.53)	21.27 (27.43)	25.12 (30.07)
T2	26.89 (31.03)	23.12 (28.69)	18.66 (25.55)	20.89 (27.19)
T3	24.77 (29.72)	23.85 (29.20)	19.44 (25.91)	21.64 27.65
T5	34.98 (36.15)	41.73 (40.20)	44.64 (41.88)	43.19 (41.05)
Overall mean	29.21	29.42	26.00	27.71
F- test	S	S	S	S
S. Ed. (±)	2.07	0.99	2.08	1.42
C. D.(P = 0.05)	4.502	2.161	4.543	3.096



Graph 3: Efficacy of Bio-Rational and Farmers Practice Module modules against *Leucinodes orbonalis* on brinjal. (Pooled data of fruit infestation 2nd and 3rd spray)



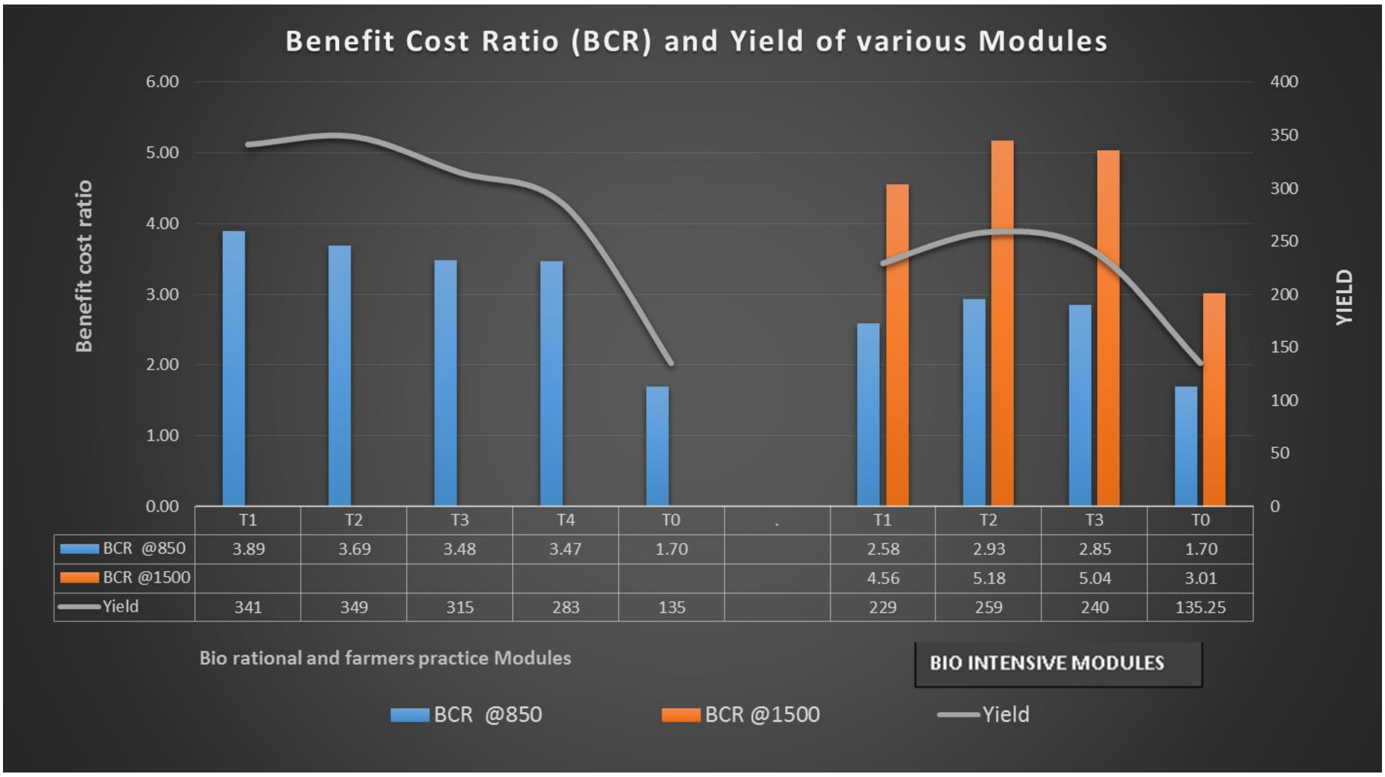
Graph 4: Efficacy of Bio Intensive modules against *Leucinodes orbonalis* on brinjal. (Pooled data of fruit infestation 2nd and 3rd spray)

Table 8: Economics of cultivation of Brinjal crop per hectare for Bio-Rational and Farmers Practice Modules@850 per/quintal

Modules	Yield of q/ha	Common cost (Rs) (Table 6)	Treatment cost (Rs)	Total cost (Rs)	Gross realization @850 Qt/ha	Gross realization @1500 Qt/ha	Total cost of yield – 10% @850 Qt/ha	Total cost of yield – 10% @1500 Qt/ha	B:C ratio @850 Qt/ha
T1	341.25	60,724.75	6325.00	67,049.75	2,90,062.50	-	2,61,056.25	-	1 : 3.89
T2	348.75	60,724.75	11655.00	72,379.75	2,96,437.50	-	2,66,793.75	-	1 : 3.69
T3	315.00	60,724.75	8485.00	69,209.75	2,67,750.00	-	2,40,975.00	-	1 : 3.48
T4	283.33	60,724.75	1780.00	62,504.75	2,40,833.33	-	2,16,750.00	-	1 : 3.47
T0	135.00	60,724.75	0	60,724.75	1,14,750.00	202500	1,03,275.00	182250	1 : 1.70

Table 9: Economics of cultivation of Brinjal crop per hectare at two different market price for Bio-Intensive Modules @850 per / quintal and @1500 per/quintal

Modules	Yield of q/ha	Common cost (Rs) (Table 6)	Treatment cost (Rs)	Total cost (Rs)	Gross realization @850 Qt/ha	Gross realization @1500 Qt/ha	Total cost of yield – 10% @850 Qt/ha	Total cost of yield – 10% @1500 Qt/ha	B:C ratio @850 Qt/ha	B:C ratio @1500 Qt/ha
T1	229.33	60,724.75	7190.00	67,914.75	1,94,933.33	344000.00	1,75,440.00	309600.00	1 : 2.58	1 : 4.56
T2	258.75	60,724.75	6770.00	67,494.75	2,19,937.50	388125.00	1,97,943.75	349312.00	1 : 2.93	1 : 5.18
T3	240.00	60,724.75	3590.00	64,314.75	2,04,000.00	360000.00	1,83,600.00	324000.00	1 : 2.85	1 : 5.04
T0	135.25	60,724.75	0	60,724.75	1,14,962.50	202875.00	1,03,466.25	182587.50	1 : 1.70	1 : 3.01



Graph 5: Benefit cost ratio and yield of various Modules

4. References

1. Alam SN, Rashid MA, Rouf FMA, Jhala RC, Patel JR, Satpathy S, *et al*. Development of an integrated pest management strategy for eggplant fruit and shoot borer in South Asia. Technical Bulletin TB28, AVRDC - The World Vegetable Center, Shanhua, Taiwan, 2003, 66-67.
2. Adiroubane D, Raghuraman K. Plant products and microbial formulation in the management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee.). Journal of biopesticides. 2008; 1(2):124-129.
3. Anonymous. Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare, 2015.
4. Bhagwan DS, Kumar A. Field efficacy of cypermethrin and certain biopesticides against brinjal shoot and fruit borer, (*Leucinodes orbonalis* Guenee) on Brinjal (*Solanum melongena* L.). Journal of Pharmacognosy and Phytochemistry. 2017; 6(4):1930-1933.
5. Bhushan S, Chaurasia HK, Shanker RAVI. Efficacy and economics of pest management modules against brinjal shoot and fruit borer (*Leucinodes orbonalis*). The Bioscan. 2011; 6(4):639-642.
6. Chawla S, Patel AR, Patel HK. Dissipation of flubendiamide in/on Brinjal (*Solanum melongena*) fruits. Environmental Monitoring and Assessment. 2011; 183:1-4.
7. Das N. Impact assessment of IPM module for management of shoot and fruit borer in Brinjal. Annals of Plant Protection Sciences. 2015; 23(1):46-48.
8. Dwivedi RK, Akhilesh T, Pal RK, Singh DK. Effect and eco-friendly management of brinjal shoot and fruit borer

(*Leucinodes orbonalis* Guenee) on brinjal. International Journal of Plant Protection. 2014; 7(2):287-291.
9. Faheem N, Sajjad A, Mehmood Z, Iqbal F, Mahmood Q, Munsif S, *et al*. The pesticide exposure through fruits and meat in Pakistan. Fresenius Environmental Bulletin. 2015; 24(12):4555-4566.
10. FAO. https://faostat.fao.org/site/567/Desktop Default. aspx? PageID=567#ancor 2016.
11. Ghosh SK, Senapati SK. Seasonal fluctuation in the population of *Leucinodes orbonalis* Guen. in the sub-himalayan region of West Bengal, India and its control on eggplant (*Solanum melongena* L.). Precision agriculture. 2009; 10(5):443-449.
12. Gomez KA, Gomez KA, Gomez AA. Statistical procedures for agricultural research. Second edition. John Wiley & Sons. New York, 1984, 690
13. Iqbal MF, Maqbool U, Asi MR, Aslam S. Determination of pesticide residues in brinjal fruit at supervised trial. Journal of Animal and Plant Science. 2007; 17(1, 2):21-23.
14. Jagginavar SB, Sunitha ND, Biradar AP. Bio efficacy of Flubendamide 480SC against brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. Karnataka Journal of Agriculture. Science. 2009; 22(3):712-713.
15. Kalawate A, Dethe MD. Bioefficacy study of biorational insecticide on brinjal. Journal of Biopesticides. 2012; 5(1):1-6.
16. Kameshwaran C, Kumar K. Efficacy of newer insecticides against the brinjal, *Solanum melongena* (L.) shoot and fruit borer, *Leucinodes orbonalis* (Guen.) in Karaikal district, UT of Puducherry. Asian Journal of Bio Science. 2015; 10(2):119-128.
17. Khajuria S, Rai AK, Lata K. Evaluation of IPM modules for the management of brinjal shoot and fruit borer. Gujarat Journal of Extension Education, 2017, 155.
18. Khorsheduzzaman AKM, Ali MI, Mannan MA, Ahmed A. Brinjal-coriander intercropping: an effective IPM component against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. (Pyralidae: Lepidoptera). Bangladesh Journal of Entomology. 1997; 7(1, 2):85-91.
19. Kodandaram MH, Rai AB, Sireesha K, Halder J. Efficacy of Cyantraniliprolee a new Anthranilic diamide insecticide against *Leucinodes orbonalis* (Lepidoptera: Crambidae) of brinjal. Journal of Environmental Biology. 2015; 36(6):1415.
20. Kumar KR, Singh NN, Raju SVS, Mishra VK. Influence of Abiotic Factors on Seasonal Incidence of Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* Guen. in Varanasi Region. International journal Current Microbiology and Applied Sciences. 2017; 6(4):1513-1518.
21. Misra HP. New promising insecticides for the management of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. Pest Management in Horticultural Ecosystem. 2008; 14(2):140-147.
22. Niranjana RF, Devi M, hilip Sridharm R. Field efficacy of insecticides for the management of brinjal Shoot and fruit borer, *Leucinodes orbonalis* Guenee. Journal of Agricultural Science and Research (JASR). 2017; 4(1):37-44.
23. Pandey R, Chaturvedi A, Chaudhary R. Effectiveness of IPM strategies against eggplant shoot and fruit borer *Leucinodes orbonalis* (Lepidoptera: Crambidae). Journal of Crop Protection. 2016; 5(4):553-563.
24. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. Indian Council of Agricultural Research (ICAR), New Delhi, 1985, 381.
25. Patel S, Mandloi R, Prajapati S, Saxena AK, Parmar R*et al*. Assessment the efficacy and economic of insecticides and bio-pesticides against major insect pest combination of brinjal (*solanum melongena* L.) cv. JB-64. Plant Archives. 2015; 15(2):923-930.
26. Patnaik HP. Flower and fruit infestation by brinjal fruit and shoot borer, *Leucinodes orbonalis* Guenee – damage potential vs. weather. Vegetable Science. 2000; 27(1):82-83.
27. Pawar DB, Bhalekar MN, Chandele AG, Ilhe BM, Shinde HN. Sex pheromone based IPM technology for brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). Pest Management in Horticultural Ecosystems. 2009; 15(2):114-120.
28. Pradhan S. Insect pests of crops. National Book Trust of India, New Delhi, 1969, 208
29. Rahman MM. Vegetables IPM in Bangladesh. In: Radcliffe's IPM World Textbook, University of Minnesota, 2007, 457-62.
30. Raina J, Yadav GS, Sharma SS. Bioefficacy of some insecticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee on brinjal under Hisar agro-climatic conditions during kharif season. Journal of Applied and Natural Science, 2016; 8(4):1801-1805.
31. Rajavel, D.S., Mohanraj, A. and Bharathi, K. Efficacy of chlorantraniliprole (Coragen 20SC) against brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.). Pest Management in Horticultural Ecosystems. 2013; 17(1):28-31.
32. Raju SVS, Bar UK, Shanker U, Kumar S. Scenario of infestation and management of eggplant shoot and fruit borer, *L. orbonalis* Guen. in India. Resistant Pest Management Newsletter. 2007; 16(2):14-16.
33. Rao GR, Kumari BR, Sahrawat KL, Wani SP. Integrated Pest Management (IPM) for reducing pesticide residues in crops and natural resources. In New Horizons in insect science: towards sustainable pest management. Springer, New Delhi. 2015, 397-412.
34. Sahu PK, Kumar A, Kujur PK. Eco-Friendly Management of Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee) in Allahabad, India. International journal Current Microbiology and Applied Sciences. 2017; 6(10):2814-2818.
35. Satpathy S, Mishra DS. Use of intercrops and antifeedants for management of eggplant shoot and fruit borer *Leucinodes orbonalis* (Lepidoptera: Pyralidae). International Journal of Tropical Insect Science. 2011; 31(1, 2):52-58.
36. Shanmugam PS, Indhumathi K, Vennila MA, Tamilselvan N. Evaluation of bio intensive pest management modules against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Crambidae) under precision farming system. Pest Management in Horticultural Ecosystems. 2015; 21(2):154-158.
37. Singh M, Sachan SK. Comparative efficacy of some bio pesticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee in brinjal. Plant Archives. 2015; 15(2):805-808.
38. Singh JP, Gupta PK, Chandra U, Singh Vimal Kumar. Bio efficacy of newer insecticides and bio pesticides

against brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). International Journal of Plant Protection. 2016; 9(1):1-7.

39. Sujayanand GK, Sharma RK, Shankarganesh K, Saha S, Tomar RS. Crop diversification for sustainable insect pest management in eggplant (Solanales: Solanaceae). Florida entomologist. 2015; 98(1):305-314.
40. Tamoghna S, Nithya C, Randhir K. Evaluation of different pest management modules for the insect pest complex of brinjal during Rabi season in zone-III of Bihar. The Bioscan. 2014; 9(1):393-397.
41. Vageeshbabu S, Hanur K, Boopal, Vijeth V, Arya K, Srividya MS. Saraswathi. Why is management of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee, difficult? An examination into the pest's unique feeding behavioral biology. Journal of Entomology and Zoology Studies. 2014; 2(6):257-260.
42. Yadav A, Sachan SK, Kumar A. Evaluation of some integrated pest management modules against shoot and fruit borer (*Leucinodes orbonalis* guenee) in brinjal (*Solanum melongena* L.). Plant Archives. 2017; 17(1): 457-462.
43. Yousafi Q, Afzal M, Aslam M, Abid AD. Effectiveness and benefit cost ratio of selected insecticides at different application on intervals for brinjal shoot and fruit borer, *Leucinodes orbonalis* (G.) management on brinjal, *Solanum melongena* (L.) at Sahiwal, Pakistan. Phytoparasitica. 2016; 44(3):423-427