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Comparative Efficacy of Certain IPM Strategies Against Tobacco Caterpillar and Head Borer in Sunflower

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ABSTRACT

The Experiments was conducted at Regional Research and Technology Transfer Station, Ranital, Bhadrak, OUAT(Odisha University of Agriculture and Technology), Odisha, India during the summer seasons(Jan-may) of 2019–20 and 2020–21 to evaluate the comparative efficacy some IPM modules against the head borer and leaf eating caterpillar in sunflower. Five IPM modules(three chemo-intensive and two bio-intensive modules) were evaluated against the existing pesticides application-based farmers' practice. The results revealed that the IPM module (M_2) comprising of installation of pheromone traps for pest monitoring @ 5 ha^{-1}, poison baits (10 kg rice bran+2 kg jaggery+100 g Thiodicarb 70WP) for attracting and killing of tobacco caterpillar larvae and alternate spray of neem oil formulations (1500 ppm) @ 1.5 l ha^{-1} and the novel insecticide mixed formulation (Novaluron 5.25%+Emamectin benzoate 0.9% SC) @ 825 ml ha^{-1} at 15 days interval had significantly suppressed tobacco caterpillar (5.46% leaf damage i.e.. 67.59% reduction over FP) and sunflower head (2.93% head damage i.e. 75.32% deduction over FP). The IPM module (M_3) comprising of pheromone trap installation @ 5 each ha^{-1},poison baits (10 kg rice bran+2 kg jaggery+200 ml deltamethrin 5EC) and alternate spray of neem oil formulations (1500 ppm) @ 1.5 l ha^{-1} and Flubendiamide 480 SC @ 150 ml ha^{-1}) also had statistically similar efficacy against the target pests with 6.40% leaf damage (62.02% reduction over FP) and 3.54% head damage(70.17% reduction over FP). Though, the BIPM module had moderate efficacy against the insect-pests under study, retained maximum population of predatory fauna like predatory bug (*Eocanthecona furcellata*) and lady bird beetles in the sunflower ecosystem.

KEYWORDS: Head borer, IPM, sunflower, tobacco caterpillar

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1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the principal and promising oilseeds crop next to groundnut, mustard and soybean in India and is making a rapid stride in the oil seed scenario of the country particularly after the inception of Technology Mission on Oil seed programme. Nutritional value of sunflower is quite promising as its seed contains 14–19% protein, 40–45% oil and 30–35% carbohydrates and its oil is rich linoleic and linoleic acid which not only look after the cardiac health of human being but also is considered to be safe for the patients having heart problem. It contains sufficient amount of calcium, iron and vitamins like A, D, E and B complex (Bhusari et al., 2018). The shortage of edible oils has become a chronic problem in India with increasing demographic pressure and sunflower can play an important role in meeting out the shortage of edible oils in the country by virtue of its shorter duration, low photo- and thermo-sensitivity and wider adaptability to different agro-ecological situations (Pattanayak et al., 2016). Though, sunflower has been proved to be as a highly promising crop under different agro-climatic regions of India, its productivity is quite low despite of the release of several hybrids and development of improved package of practices**.** The production and productivity of sunflower is greatly constrained by various biotic factors and among them insect pest cause substantial yield loss in this crop. Though about 251 insect-pests are reported to infest the sunflower crop, defoliators, head borers, leafhoppers, thrips and whiteflies are considered as the key pests (Naresh Kumar et al., 2017 and Rana et al., 2004). In the recent past, insect pest outbreaks pose serious threat to profitable production of sunflower in different parts of India (Jayewar and Sonkamble, 2015). Among these the polyphagous insect-pests like tobacco caterpillar (*Spodoptera litura*) and head borer (*Helicoverpa armigera*) are assuming serious significance under the changing climatic scenario. Particularly the head borer, *Helicoverpa armigera* has attained the status of a national pest as it inflicts substantial yield loss to a large number of cultivated crops including sunflower (Singh and Singh, 2006).One of the major reasons attributed to the decline in the cultivated area under sunflower in different states is the widespread outbreak of these insect-pests (Basappa, 2011). The productivity of sunflower is limited mainly due to the heavy damage inflicted by the capitulum borer resulting in yield losses of 20–25% under normal conditions however, in certain cases; the damage is so severe that the loss can surpass 40–70% (Ranasingh and Mahalik, 2008). In some areas, heavy infestation of *H.armigera* (83.6%) was observed with as many as six larvae per head (Jagadish et al., 2016).

Farmers mostly depend on the chemical pesticides for minimizing the pest infestation in sunflower and repeated application of highly toxic conventional pesticides, their various combination products and cocktail mixtures have serious undesirable consequence on human health and crop ecosystem. Pesticide residues in food, soil, water and environment, development of resistance to insecticides, resurgence of sucking pests, outbreak of minor pests, widespread killing of non-target organisms like predators, parasitoids and pollinators necessitates the adoption of suitable Integrated Pest Management (IPM) strategy for managing the insect pest of sunflower with little adverse effect on environment. In the recent years emphasis is being given on the use of botanicals, bio-pesticides and newer insecticidal molecules which can be suitably acceptable in integrated pest management programme. Keeping this in view the present investigation was carried out to evaluate Integrated pest management (IPM) modules in sunflower against head borer and tobacco caterpillar ".

2. MATERIALS AND METHODS

Field trials were carried to evaluate the comparative efficacy of different IPM modules against head borer **(***Helicoverpa armigera*) and tobacco caterpillar *Spodoptera litura*during the summer seasons 2019–20 and 2020–21 at the experimental plots of Regional Research and Technology Transfer Station (RRTTS), Ranital situated in the Bhadrak district of Odisha, India (21.1463^0 N, 86.5656^0 E) which comes under the North Eastern Coastal Plain Agro-climatic Zone of the state. Five IPM modules (Table 1) were tested for their efficacy against the existing farmers' practice of indiscriminate use of chemical pesticides and each module was considered as one treatment. The experiments were laid out in randomised block design with six treatments and four replications. The bio-intensive modules (T_4 and T_5) were laid out separately from the chemo-intensive modules (T_1, T_2 and T_3) at an isolation distance of 50 m from each other to avoid the negative effect of chemicals on bio agent activity. A popular sunflower hybrid, Aruna was sown in the well prepared plots of size 7×4 m^2 on 15.1.2020 and 18.1.2021 for both the years of experiment, respectively. The crop was grown with their recommended agronomic package of practices, with a spacing of 60×30 cm^2 and fertilizer doses of 90, 90 and 60 kg N, P_2O_5, and K_2O ha^{-1}, respectively. For maintaining optimal plant growth and vigour, standard intercultural operations and judicious water management practices were used.

The pheromone traps (funnel trap) were installed in the experimental plots ensuring the lure position at 45 cm above the crop canopy and the lures were changed at every three weeks' interval. The spraying of insecticides and bio pesticides was done with the help of manually operated Knapsack sprayer using 500 l of spray volume ha^{-1}. In poison bait placement rice bran and jaggery were mixed with little water during the morning hours and allowed for fermentation for 8 to 10 h. The insecticides were mixed with the fermented mixture during the evening hours and placed in the plots for attracting and killing the nocturnal larvae of tobacco caterpillar.

Treatment and replication wise observations on the infestation of tobacco caterpillar were taken from 21 days after sowing till the harvest of crop. Percent leaf damage was assessed by counting the infested and healthy leaves of 10 randomly selected tagged plants in each plot at weekly interval. The larval population of *Spodoptera litura* in the tagged plants was counted during each observation and the average larval population was expressed as larval intensity. Similarly, observations on the infestation of sunflower head borer were recorded from the initiation of damage in the tagged plant still the final harvest of crop. Percent head damage was estimated from the cumulative counts of the total and infested heads during the crop period. The larval population of *Helicoverpa armigera*in the tagged plants was counted during each observation and the average larval population was expressed as larval intensity. The data on the Percent leaf damage by tobacco caterpillar and head damage by head borer and larval intensity of these two pests were subjected to statistical analysis after necessary transformation to evaluate the efficacy of the IPM modules. During both the years of experiment predatory bug and lady bird beetles were found to be the major natural enemies found in the sunflower ecosystem. Weekly observations on the population of these predators were recorded from M_1 randomly selected tagged plants in each plot from 21 days after sowing. The mean population data were analyzed to study the comparative safety of IPM modules over the indiscriminate pesticide application-based farmers' practice. The effect of various IPM modules evaluated for their efficacy against the major insect-pests of sunflower was also studied for their effect on crop yield and economics. Treatment and replication wise crop yield was recorded during the harvest and converted to ton ha^{-} for analysis. Similarly, avoidable yield loss was worked out with respect to treatments in which maximum yield was obtained (Mathur and Jain, 2009).

Table 1:IPM Modules tested against *Spodoptera litura* and *Helicoverpa armigera* during 2019–20 and 2020–21

Treatments	Details of the Technology
T_1: IPM Module 1	Pheromone Trap installation for monitoring of head borer and leaf eating caterpillar @ 5 each ha^{-1} +Poison bait placement (10 kg rice bran+2 kg jaggery+250 ml Lambda cyhalothrin 5EC) for attracting and killing of tobacco caterpillar larvae+Alternate spray of neem oil formulations (1500 ppm) @ 1.5 l ha^{-1} and (Indoxacarb 4.5%+Novaluron 5.25% SC) @ 825 ml ha^{-1} at 15 days interval
T_2: IPM Module 2	Pheromone Trap installation for monitoring of head borer and leaf eating caterpillar @ 5 each ha^{-1} +Poison bait placement (10 kg rice bran+2 kg jaggery+100 g Thiodicarb 70WP) for attracting and killing of tobacco caterpillar larvae+Alternate spray of neem oil formulations (1500 ppm) @ 1.5 L ha^{-1} and (Novaluron 5.25%+Emamectin benzoate 0.9% SC) @ 825 ml ha^{-1} at 15 days interval
T_3: IPM Module 3	Pheromone Trap installation for monitoring of head borer and leaf eating caterpillar @ 5 each ha^{-1} +Poison bait placement (10 kg rice bran+2 kg jaggery+200 ml deltamethrin 5EC) for attracting and killing of tobacco caterpillar larvae. +Alternate sprayofneem oil formulations (1500 ppm) @ 1.5 l ha^{-1} and Flubendiamide 480 SC@ 150 ml ha^{-1} and at 15 days interval
T_4: IPM Module 4 (Bio-intensive)	Pheromone Trap installation for monitoring of head borer and leaf eating caterpillar @ 5 each ha^{-1} +Trap cropping with marigold+Release of bio agent *Trichgramma. Chilonis* @ 1 lakh ha^{-1} 3 times at 15 days interval+Alternate need based application of Neem oil formulations (1500 ppm) @ 1.5 l ha^{-1} and Bt @ 1 kg ha^{-1} at 15 days interval+Poison bait placement (10 kg rice bran+2 kg jaggery+40 ml Spinosad 45SC) for attracting and killing of tobacco caterpillar larvae
T_5: IPM Module 5 (Bio-intensive)	Pheromone Trap installation for monitoring of head borer and leaf eating caterpillar @ 5 each ha-1 +Intercropping with coriander+Release of bioagent *Trichgramma. chilonis* @ 1 lakh ha^{-1} 3 times at 15 days interval+Alternate need based application of Neem oil formulations (1500 ppm) @ 1.5 l ha^{-1} andBeauveria bassiana @ 1.25 l ha^{-1} at 15 days interval+Poison bait placement (10 kg rice bran+2 kg Jaggery+50 g Emamectin benzoate 5 SG) for attracting and killing of tobacco caterpillar larvae
T_6: Farmers' practice	Spraying of Lambda cyhalothrin 4.9 CS (625 ml ha^{-1}), Chlorpyriphos+Cypermethrin (1.25 ml ha^{-1}).

Percent avoidable yield loss=Yield abtained from the most effective module- yield obtained from the reference nodule /yield obtained from the most effective module ....(1)

Based on the mean yield data of two years of experimentation, comparative economics was calculated in terms of B:C ratio and incremental B:C ratio for studying the economic feasibility of the IPM modules. For obtaining gross return the minimum support price (MSP) of sunflower was taken into consideration. The crop protection expenses were calculated by adding the cost of individual IPM components and the expenditure incurred towards spraying of the insecticides and bio-pesticides.

3. RESULTS AND DISCUSSION

3.1. Effect of different IPM modules on tobacco caterpillar (Spodoptera litura)

Pooled data analytics of both the years of experiment as depicted in (Table 2) indicated that all the IPM modules reduced the larval intensity to a significant level and the effect of different modules was found to have significant advantageous over the farmers' practice. The module M_2 was observed to be the most effective IPM strategy as it minimized the larval intensity to mere 0.71 larvae plant^{-1} (74.32% reduction over farmers' practice), closely followed by M_3 (0.82 larvae plant^{-1} i.e. 70.13% reduction over farmers' practice) and both these modules were statistically comparable with each other. The module M_1 with 1.20 larvae plant^{-1} (56.47% reduction over farmers' practice) was the effective treatment. On the other hand, the two bio-intensive modules remained as moderately effective in dropping the larval intensity of *Spodoptera litura* and the total mean larval intensity in these modules were1.71 larvae plant^{-1} in M_4 (37.57% reduction over FP) and 1.83 larvae plant^{-1} in M_5 (33.38% reduction over FP). In contrast the maximum larval population was observed in the farmers' practice (2.75 larvae plant^{-1}).

Similarly, the pooled data on the extent of leaf damage (Table 2) over both seasons of experiment indicated that though all the IPM modules reduced the leaf infestation significantly over the farmers' practice, the module M_2retained its superiority as it minimized the leaf damage to only 5.46% (67.58% reduction over farmers' practice) closely followed by M_3 with 6.40% leaf damage (62.02% reduction over farmers' practice). The bio-intensive module M_4 with 10.44% leaf damage (38.06% reduction over FP) and M_5 with 11.71% leaf damage (30.53% reduction over FP) remained at par with each other and significantly superior to farmers' practices which witnessed the maximum leaf damage of 16.85%.

Table 2: Effect of different IPM modules on larval intensity and damage of *Spodoptera litura* and *Helicoverpa armigera* and effect on natural enemies population of sunflower ecosystem (2019–20 and 2020–21)

IPM modules	Larval intensity (Average number of larvae plant^{-1})*				Damage (%)**				Population of natural enemies (Average number plant^{-1})*			
	S. litura		*H.armigera*		*S.litura*		*H. armigera*		Predatory bug		Lady bird beetle	
	Pooled mean Mean	Percent reduction over FP	Mean	Percent reduction over FP	Mean	Percent reduction over FP	Mean	Percent reduction over FP	Mean	Percent increase over FP	Mean	Percent increase over FP
M_1	1.20 (0.34)	56.47	0.57 (0.19)	61.84	8.17 (2.85)	51.55	4.91 (2.21)	58.62	1.02 (0.30)	61.90	0.89 (0.28)	56.14
M_2	0.71 (0.23)	74.32	0.29 (0.11)	80.20	5.46 (2.33)	67.58	2.93 (1.71)	75.32	1.16 (0.33)	84.13	0.96 (0.29)	68.14
M_3	0.82 (0.26)	70.13	0.36 (0.13)	75.91	6.40 (2.52)	62.02	3.54 (1.88)	70.19	1.27 (0.35)	101.58	1.07 (0.31)	87.72
M_4	1.71 (0.43)	37.57	0.83 (0.26)	44.06	10.44 (3.23)	38.06	7.13 (2.67)	39.92	1.69 (0.43)	168.25	1.50 (0.40)	163.15
M_5	1.83 (0.45)	33.38	0.91 (0.28)	38.84	11.71 (3.42)	30.53	8.04 (2.83)	32.26	1.79 (0.44)	184.12	1.68 (0.43)	194.73
FP	2.75 (0.57)		1.48 (0.39)		16.85 (4.10)		11.87 (3.44)		0.63 (0.21)		0.57 (0.19)	
SEm±	0.017		0.013		0.085		0.064		0.014		0.015	
CD (p=0.05)	0.05		0.04		0.26		0.20		0.04		0.05	

*: Figures in the parentheses are the (log x+1) transformed values); **: Figures in the parentheses are the square root transformed values, FP: Farmers' practice

The results of the present investigation derived ample support from the findings of Jagadish et al. (2010) who reported that pheromone trap installation could effectively monitored the outbreak of *S. litura* moths in sunflower and thus plan for timely implementing the IPM interventions against this pest. He further revealed that foliar spray of both Neem gold (300 ppm Azadirachtin) and Neem Seed Kernel Extract @ 5% were significantly superior in the suppression of *S. ltura* in sunflower with 91.0 and 75.7% reduction over the untreated control, respectively up to50 days after sowing. Ghosal et al. (2017) mentioned that (Novaluron 5.25%+Emamectin benzoate 0.9%) SC is highly effective against *Spodoptera litura.* Further Sreedhar (2018) revealed that (Novaluron 5.25%+Emamectin benzoate 0.9%) SC @ 0.012% recorded more than 90% larval mortality of tobacco caterpillar in tobacco. Regarding the efficacy of poison bait on the suppression of larval infestation of *S.litura*, Muddasar et al. (2017) reported that a jaggery-based poison bait (Rice bran+jaggery 20%+yeast 0.1%+Spinopsad @ 2.5 ml kg^{-1}) was the most effective in lowering larvae population *Spodoptera litura* and leaf damage.

3.2. Effect of different IPM modules on sunflower head borer (Helicoverpa armigera)

The mean data of both the years of experiment (Table 2) concluded that all the IPM modules significantly reduced the larval population of sunflower head borer as compared to the existing farmers' practice. The module M_2 was found to be the most effective as it minimized the larval intensity to only 0.29 larvae plant^{-1} (80.20% reduction over farmers' practice) followed by M_3 with 0.36 larvae plant^{-1} (75.91% reduction over farmers' practice) and M_1 with 0.57 larvae plant^{-1} (61.84% reduction over farmers' practice). However, the IPM modules M_2 and M_3 did not differ significantly and therefore, can be considered equally effective against the sunflower head borer. Though both the bio intensive modules offered significantly superior control over the farmers' practice (44.06 and 38.84% reduction in M_4 and M_5, respectively), their efficacy remained fairly efficient in comparison to chemo intensive modules.

The results of pooled analysis on the extent of head damage (Table-2) indicated that the intensity of damage was the highest (11.87%) in the farmers' practice and the damage was significantly lower in all the IPM plots. The module M_2 was observed to have the maximum efficacy with a minimum flower head infestation of 2.93% (75.32% reduction over FP) closely followed by M_3 with 3.54% (70.19% reduction over FP) and both the modules were statistically similar to each other. The module M_1 with 4.91% head damage (58.62% reduction over FP) retained third position in its efficacy against head borer. All these three chemo-intensive modules resulted in an appreciable reduction in the flower head damage when compared to the farmers practice. All the bio-intensive modules remained moderately effective in reducing the flower head damage and the overall mean flower head infestation in these modules ranged from 7.13% (39.92% (reduction over farmers practice) in M_4 to 8.04% (32.26% reduction over farmers practice) in M_5.

The result of investigation derived support from the findings of Kailas et al. (2017) who reported that Emamectin Benzoate was most effective against *Helicoverpa armigera*. Bilash et al. (2022) reported that Flubendiamide is the best treatment *Helicoverpa armigera* which recorded minimum mean population of 0.98 larvae plant^{-1} and 80.71% reduction over control. Thilagam et al. (2010) opined that flubendiamide 480 SC was considerably superior in lowering *H. armigera* larval population in cotton.

3.3. Effect of IPM modules on the natural enemies in sunflower eco-system

During the course of investigation, though a diverse population of beneficial Arthropods was noticed in the sunflower ecosystem, predatory bugs and lady bird beetles were found to be the most dominant with higher abundance level. The population of predatory bugs and ladybird beetles in different IPM plots and the plots under the farmers' practice has been presented in Table 2 to observe the effect of IPM and farmers' practice on these beneficial fauna.

The superiority of IPM plots in retaining predatory bug population was also revealed by the pooled mean data from the two years' experiment (Table 2). In comparison to farmers' practice, the bio-intensive modules fostered much higher populations of predatory bugs, ranging from M_1.79 plant^{-1} in M_5 (184.12% increase over FP) to 1.69 plant^{-1}in BIPM module M_4 (168.25% increase over FP). Among chemo-intensive module, the predatory bug population was highest in module M_3 with 1.27 bug plant^{-1} (101.58% increase over FP) followed by M_2 (1.16 bugs plant^{-1} i.e. 84.13% increase over FP) and M_1 (1.02 bugs plant^{-1} i.e. 61.9% increase over FP). The minimum predatory bug population was found in farmers' practice (0.63 bugs plant^{-1}) largely due to the adverse effect of indiscriminate application of toxic insecticides. Comparatively higher predatory bug population in the chemo-intensive IPM modules indicated the safety of neem based formulations and new generation pesticides. The higher predatory bug activity in the BIPM modules justified its valuable ecosystem benefits of non-chemical based pest management strategies.

The combined mean value of the two years of experiments as depicted in (Table 2) revealed that there was a significant increase in ladybird population in the bio-intensive IPM plots, with IPM module M_5 retaining 1.68 lady birds plant^{-1} (a 194.73% increase over FP) and M_4 recording 1.50 beetle splant^{-1} (163.15% increase over FP). In the chemo-intensive module the ladybird beetle population ranged from M_1 0.07 beetles plant^{-1} in M_3 to 0.98 beetle plant^{-1}in M_1. All the modules were found to be superior in terms of their safety to the natural enemies. However, the farmers' practice had a very low population of ladybird beetles (0.57 beetles plant^{-1}) indicating the hazardous effect of chemical pesticides. The finding of present study get enough support from the finding of Kailas et al. (2017), further revealed that Emamectin benzoate has no noticeable adverse impact on natural enemies.

3.4. Effect of IPM modules on seed yield and economics of sunflower

The pooled mean data on crop yield obtained during both the years of investigation revealed that the module M_2 registered the highest seed yield of 1698 kg ha^{-1} (53.93% increase over FP) and was statistically comparable with M_3 1648 kg ha^{-1} (49.41% increase over FP). Seed yield of 1487 kg ha^{-1} (34.81% increases over FP) obtained from M_1 which was found to be the next in order of its efficacy. The bio-intensive modules produced comparatively less seed yield of 1317 kg ha^{-1} (19.40% increase over FP) in M_4 and 1271 kg ha^{-1} (15.23% increase over FP) in M_5 but were significantly superior to farmers' practice, where the lowest seed yield of 1103 kg ha^{-1} was obtained. The findings also suggested that adoption of appropriate IPM strategy can contribute towards 50% higher yield in sunflower crop due to effective suppression of pest infestation by the major insect-pests i.e. *Spodoptera litura* and *Helicoverpa armigera*. The percent avoidable yield loss was also calculated with reference to the most effective IPM module. The maximum avoidable yield loss was obtained in the farmers' practice which indicated that had the best IPM module adopted, the yield loss of 35.04% could have been avoided. Percent avoidable yield loss of 22.44 and 25.15 was estimated in the bio-intensive modules M_4 and M_5, respectively. Among the chemo-intensive modules the maximum avoidable yield loss was found in the module

The economics of various pest management modules and the farmers' practice was calculated based on gross return, net returns gained, B:C ratio and incremental B:C ratio and was presented in the Table 3. The highest net return from sunflowerha^{-1}was recorded in the module M_2 (₹ 46290.00) due to the maximum yield advantage over other IPM modules and the farmers' practice closely followed by the module M_3, where a net return of ₹ 43770.00 was achieved. The other chemo-intensive module under study i.e. M_1 registered a net return of ₹ 35235.00 and therefore was considered to be next economical treatment. A comparatively less net return was obtained from the bio-intensive modules (₹ 26675.00 and ₹ 24505.00 in M_4 and M_5, respectively) due to the moderate level of protection against insect-pests. The minimum net return of ₹ 17465.00 was calculated from the farmers' practice. The highest B:C and incremental B:C ratio of 1.98 and 8.39 was obtained in the module M_2 which was slightly higher than the module M_3, where B:C and incremental B:C ratio of 1.93 and 8.17, respectively was obtained. The chemo-intensive module M_1 with B: C and incremental B:C ratio of 1.76 and 6.30, respectively, was found to be marginally less economically viable. Among the bio-intensive modules the B:C and incremental B:C ratio of 1.58 and 4.60 was obtained from M_4 and that of M_5 was found to be 1.54 and 4.20, respectively. The lowest B:C ratio of 1.40 was found in the farmers' practice. The results so obtained indicated that IPM modules are not only effective in suppressing the pest infestation but also economically viable with higher return and benefit cost ratio.

Table 3: Effect of different IPM modules on seed yield and economics of sunflower product

IPM module	Sunflower yield in kg ha^{-1}			Economics				
	Mean	Percent increase over FP	Percent avoidable yield loss	Gross return* (US$)	Cost of production (US$)	Net return (US$)	B:C ratio	Incremental B:C ratio
M_1	1487	34.81	12.80	1075.44	612.11	463.32	1.76	6.30
M_2	1698	53.93	-	1228.03	619.34	608.69	1.98	8.39
M_3	1648	49.41	2.94	1191.87	616.31	575.55	1.93	8.17
M_4	1317	19.40	22.44	952.48	601.72	350.76	1.58	4.60
M_5	1271	15.23	25.15	931.46	596.98	322.22	1.54	4.20
FP	1103		35.04	797.71	568.06	229.65	1.40	
SEm±	40.278							
CD (p=0.05)	121.36							

1US$=INR 76.0482 (Avg. month value of March, 2022)

4. CONCLUSION

The IPM module comprising of pheromone traps, poison baits, spraying of neem oil and (Novaluron 5.25%+Emamectin benzoate 0.9% SC) was found to be highly efficient in minimizing the infestation of *Spodoptera litura* and *Helicoverpa armigera* in sunflower. The BIPM modules had moderate efficacy against both the target pest and retained the maximum population of beneficial fauna. Hence, by adoption of integrated approach, the farmers can minimize the pest damage and reduce the plant protection cost with higher productivity and profitability.

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