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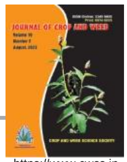

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Evaluation of different integrated pest management modules against major pests of field pea

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ABSTRACT

The present investigation was conducted to compare the feasibility and economic viability of three integrated pest management packages including farmers' practices for controlling field pea pests during winter seasons of 2016-17, 2017-18 and 2018-19 at DSF (AB Block) of Bidhan Chandra Krishi Viswavidyalaya located at Kalyani, Nadia, West Bengal. The Integrated Pest Management (IPM) modules are made up with integration of different management strategies viz. seed treatment, use of biorational and new generation insecticides having novel mode of action. Module 2 was proved superior to other modules in respect of managing pod borer infestation and giving highest yield and net return. However, Module 3 was found highly effective for suppressing the aphid population as well as reflection of highest incremental benefit cost ratio. Module 4 i.e. farmers' practice was the least effective regarding reducing pest infestation as well as producing yield. The present experimental findings can be used as alternatives for conventional farmer's practices and these will certainly be more cost effective and beneficial for the farming community.

Keywords **:** *Aphis craccivora*, Economics, Efficacy, Field pea, *Helicoverpa armigera*, IPM, *Pisum sativum*

In Indian agriculture one of the vital components is pulse cultivation. Pulses contain 23-25% protein, which is almost twice or thrice as compare to protein content of cereals like wheat, rice etc. (Anon., 2012). All legumes have major contribution in human and animal nutrition and also help to maintain sustainable development in agriculture. For creating worldwide awareness to improve current and future pulse production and productivity, Food and Agriculture Organization (FAO) of the United Nations had declared the year 2016 as the 'International Year of Pulses' (FAO, 2016). *Pisum sativum* (L), commonly known as field pea is cultivated on commercial scale in the world over. India, globally a major field pea producing country, is ranked 5th in the list of pea producing nations (Anon., 2014). Nowadays the production of pea is challenging due to infestation of different insect pests in field as well as in storage viz. pod borers, aphids, thrips, whitefly, pulse beetle etc. Prasad *et al.* (1983) reported 19 insect pest species from pea among which eight were with most importance. In West Bengal condition, amongst the various pests, sap-sucking pest pulse aphid [*Aphis craccivora* (Koch.)] and pod boring pest *Helicoverpa armigera* (Hub.) are considered as the major damaging pests of pea. This pod borer species is very dangerous and it is considered to be a national pest in India, causing 10-30% grain damage (Quadeer and Singh, 1989). Therefore, proper pest management is an important aspect to increase pea production. According to Tanweer and Rao (1997), implementation of different management practices in a holistic way provides a meaningful control of *H. armigera*. The Central Insecticide Board has prescribed huge number of toxicants against the pod borers. But most of the farmers in our country follow the advice of pesticide dealers to control the insect pest population. Recently number of articles is published which tells about the disappointing fates of insecticides in controlling pest population by developing resistance and resurgence capacity among the pests (Mathews, 1993; Ahmad *et al*., 1997). The situation has come for wide-angled researches to create and evaluate IPM packages which contain all potential practices of pest management like growing pest resistant cultivars, control through mechanical and agronomic practices, behavioral approach, bio-intensive approach, chemical control etc. (Jayaraj, 1992). This may offer a more sustainable approach to manage the pests and enhance economic viability. In IPM, use of chemical pesticides should be minimized as the potential of environmental hazard can be reduced. On the other hand, new generation insecticide molecules are less toxic to humans and other animals and also have high potency to check the pest resistance against insecticides. Therefore, according to Gnanasambandan *et al.* (2004),

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the basic importance of IPM is recent adoption which maintains the movement of sustainable agriculture. The focus of the current study was to evaluate some IPM modules against field pea pests particularly in alluvial plains of eastern India.

MATERIALS AND METHODS

The field trials were conducted during winter seasons of three successive years viz. 2016-17 to 2018-19 at AB Block Farm (District Seed Farm) of the university located at Kalyani, Nadia, West Bengal to evaluate three different IPM modules towards controlling major field pea pests along with farmers' practices. The seeds of field pea (var. Rachna) were sown during last week of November in all three seasons. Randomized complete block design (RBD) was followed for the experiment which was replicated thrice. The dimension of each plot was 4 m in length and 3 m in breadth as well as 30 cm gap between two adjacent rows and 10 cm gap between two plants within each row was maintained. Different components of the IPM modules were as follows. Module 1 (i.e. Treatment 1) comprised of seed treatment with Imidacloprid 600 FS and Carbendazim 50 WP (@ 3 ml + 2 g kg^{-1} of seed), *Rhizobium* treatment + PSB + PGPR, application of Neem Seed Kernel Extract (NSKE), a botanical insecticide at 5 per cent at 40 days after sowing (DAS) and spraying with Indoxacarb14.5 SC (a chemical insecticide) @ 50 g a.i. ha^{-1} at 50% flowering stage. Module 2 (i.e. Treatment 2) comprised of similar kind of seed treatment and botanical insecticide application as followed in Module 1 but here as chemical insecticide, Chlorantraniliprole 18.5 SC @ 20 g a.i. ha^{-1} was sprayed instead of Indoxacarb. Module 3 (i.e. Treatment 3) followed similar kind of treatments like Module 1 and Module 2 but Spinosad 45 SC @ 73 g a.i. ha^{-1} was applied here as chemical insecticide. Module 4 (i.e. Treatment 4) comprised of only application of chemical insecticide (Cypermethrin 10 EC @ 0.005%) but it was sprayed three times at vegetative stage, flower bud initiation stage and pod formation stage, respectively. In Module 1, Module 2 and Module 3, *Rhizobium* treatment will be done after 24 hours of insecticide and fungicide treatment. After mixing *Rhizobium*, PSB and PGPR @ 200 g acre^{-1} each in the ratio of 1:1:1 will be treated on seed. The pest data recording was started when the plant age was 21 days and it was continued till harvesting of the crop. For taking observations 10 plants were randomly selected from each replication and tagged them with paper cards. In every week each tagged plant was carefully examined in morning time made to determine the impact of different module. To determine pod borers infestation level in the field, weekly larval count (plant wise) was recorded. However, total number of nymphs and adults of aphid per 10 cm apical twig from each sampled plant was recorded. The observations on the population of natural enemies per plant (adult and grub of Coccinellid beetle) were also recorded. To estimate the pod damage percentage, total number of pods as well as number of damaged pods on single plant basis was counted during harvest. The technique of 'Analysis of Variance' (ANOVA) was used for data analysis and the results were tested for significance (Panse and Sukhatme, 2000). The yield obtained from each treatment was also recorded after harvest of the crop (gram per plot basis) and afterwards the yield values were transformed in to kilogram per hectare. To assess the monetary gain of the studied treatments, the expenditures due to plant protection measures along with total income generated from each test module were taken into consideration and afterwards Incremental Benefit Cost Ratio (IBCR) was calculated.

RESULTS AND DISCUSSION

In the present study, bio-efficacy of three different IPM modules along with farmers' practice in field pea was evaluated in terms of pest infestation and presence of natural enemy during crop growing period as well as per cent pod damage and yield obtained at harvest.

Impact of different test modules on insect pest population

The results due to effect of different test modules on pest incidence during 2016-17, 2017-18 and 2018-19 are presented in Table 1, 2, 3 (experimental year wise) along with Figure 1 and 2 (pest wise), respectively. The findings divulge that all the three IPM modules were observed to be significantly better than farmers' practices in minimizing insect pest infestation. During 2016-17, the populations of *H. armigera* in the three IPM modules were significantly differed from T_4 but the population in T_2 and T_3 were statistically at par with each other. During overall crop growing period, highest gram pod borer population was recorded from farmers' practice i.e. T_4 (6.01 larvae plant^{-1}) and followed by T_1 (seed treatment + NSKE 5% + Indoxacarb 14.5 SC @ 50 g a.i. ha^{-1}) with 3.18 larvae plant^{-1}, T_3 (seed treatment + NSKE 5% + Spinosad 45 SC @ 73 g a.i. ha^{-1}) with 1.21 larvae plant^{-1} and T_2 (seed treatment + NSKE 5% + Chlorantraniliprole 18.5 SC @ 20.0 g a.i. ha^{-1}) with 1.07 larvae plant^{-1}. In case of aphid, maximum population was recorded from T_4 (10.64 aphids plant^{-1}) and minimum population from T_3 (2.59 aphids plant^{-1}). This result suggests that the farmers' practices are least effective in controlling the pest population. During 2017-18, among the different modules evaluated, the Module 2 (i.e. T_2) was proved to be the most effective in lowering gram pod borer number with a mean value

Table 1: Impact of different test modules on pest population, pod damage and yield of field peaduring 2016-17

Treatments	Mean insect pest population		Pod damage (%)	Yield (kg ha^{-1})	Increase in yield over T_4 (%)
	Gram pod borer (larvae plant^{-1})	Aphid (nymphs + adults 10^{-1} cm apical twigs plant^{-1})			
T_1	3.18 (1.8)*	6.95 (2.6)	8.64 (1.7)**	1138.89 (33.8)	15.49
T_2	1.07 (1.0)	5.24 (2.3)	3.38 (1.1)	1375.00 (37.1)	39.44
T_3	1.21 (1.1)	2.59 (1.6)	3.56 (1.1)	1361.11 (36.9)	38.03
T_4	6.01 (2.5)	10.64 (3.3)	31.02 (3.2)	986.11 (31.4)	-
SEm (±)	**0.16**	**0.17**	**0.05**	**0.26**	**-**
LSD (p=0.05)	**0.57**	**0.59**	**0.17**	**0.91**	**-**

**Figures in parentheses are square root transformed values*
*** Figures in parentheses are arc sine transformed values*

Table 2 : Impact of different test modules on pest population, pod damage and yield of field pea during 2017-18

Treatments	Mean insect pest population		Pod damage (%)	Yield (kg ha^{-1})	Increase in yield over T_4 (%)
	Gram pod borer (larvae plant^{-1})	Aphid (nymphs + adults 10^{-1} cm apical twigs plant^{-1})			
T_1	2.53 (1.6)*	9.42 (3.1)	7.00 (1.5)**	1138.89 (33.8)	28.13
T_2	0.71 (0.9)	6.87 (2.6)	1.67(0.8)	1222.22 (35.0)	37.50
T_3	1.49 (1.2)	4.65 (2.2)	4.53(1.2)	1208.33 (34. 8)	35.94
T_4	4.68 (2.2)	13.86 (3.7)	15.60(2.3)	888.89 (29.8)	-
SEm (±)	**0.28**	**0.21**	**0.06**	**0.67**	**-**
LSD (p=0.05)	**0.99**	**0.72**	**0.19**	**2.33**	**-**

**Figures in parentheses are square root transformed values*
*** Figures in parentheses are arc sine transformed values*

Table 3: Impact of different test modules on pest population, pod damage and yield of field pea during 2018-19

Treatments	Mean insect pest population		Pod damage (%)	Yield (kg ha^{-1})	Increase in yield over T_4 (%)
	Gram pod borer (larvae plant^{-1})	Aphid (nymphs + adults 10^{-1} cm apical twigs plant^{-1})			
T_1	1.04(1.02)	5.94(2.43)	4.73(1.25)	1225.00(35.01)	8.89
T_2	0.02(0.17)	4.68(2.16)	0.44(0.40)	1525.00(39.06)	35.56
T_3	0.38(0.62)	1.93(1.39)	2.48(0.91)	1350.00(36.76)	20.00
T_4	2.86(1.69)	9.32(3.05)	9.08(1.73)	1125.00(33.57)	-
SEm (±)	**0.22**	**0.21**	**0.08**	**0.27**	**-**
LSD (p=0.05)	**0.78**	**0.74**	**0.29**	**0.95**	**-**

**Figures in parentheses are square root transformed values*
*** Figures in parentheses are arc sine transformed values*

Table 4: Effect of different test modules on natural enemy population in field pea ecosystem

Treatments	Mean coccinellid population (adults and grubs per plant)		
	2016-17	**2017-18**	**2018-19**
T_1	2.25 (1.50)	2.21 (1.42)	3.17 (1.78)
T_2	4.06 (2.01)	5.17 (2.27)	5.38 (2.32)
T_3	3.78 (1.95)	5.02 (2.24)	5.12 (2.26)
T_4	1.47 (1.21)	1.44 (1.20)	2.27 (1.51)
SEm (±)	**0.06**	**0.12**	**0.08**
LSD (p=0.05)	**0.20**	**0.40**	**0.26**

**Figures in parentheses are square root transformed values*

Table 5: Economics of different test modules

Treatment	Yield* (kg/ ha)	Cost of cultivation* (Rs ha^{-1})	Gross return* (Rs ha^{-1})	Net return (Rs ha^{-1})	IBCR
T_1	1167.59	27625	69513	41888	1.52
T_2	1374.07	30486	81632	51146	1.68
T_3	1306.48	28157	78142	49985	1.78
T_4	1000.00	24312	58219	33907	1.39

** Pooled mean of three years*

[Considered cost: Imidacloprid 600 FS = Rs. 550 per 100 ml, Carbendazim 50 WP = Rs. 500 per 500 g, Rhizobium = Rs. 60 per kg, PSB = Rs. 80 per kg, PGPR = Rs. 60 per kg, NSKE powder = Rs. 1500 per 5 kg, Indoxacarb14.5 SC = , Chlorantraniliprole 18.5 SC = Rs. 185 per 10 ml, Spinosad 45 SC = Rs. 1700 per 75 ml, Cypermethrin 10 EC = Rs.240 per litre, Pesticide application cost = Rs. 300 per labour, Selling price of field pea = Rs. 35 per kg]

of 0.71 larvae plant^{-1} while maximum pod borer population was recorded from T_4 (4.68 larvae plant^{1}). The aphid population was also significantly lower in T_3 (4.65 aphids plant^{-1}) which was followed by T_2 (6.87 aphids plant^{-1}) and T_3 (9.42 aphids plant^{-1}), while, maximum aphid population was noticed in farmers' practice i.e.T_4 (13.86 aphids plant^{-1}) despite of scheduled based application of chemical insecticide (Cypermathrin 10 EC @ 0.005% at vegetative, flower bud initiation and pod formation stage of the crop). During 2018-19 also, the density of pest population in the IPM modules were dramatically less compare to farmers' practice plot. Overall comparison of treatments showed that minimum population of *Helicoverpa* borer was recorded from T_2 with a value of 0.02 larvae plant^{-1} followed by T_3 (0.38 larvae plant^{-1}) and T_1 (1.04 larvae plant^{-1}). All these modules significantly lowered gram pod borer population excepting T_4 (2.86 larvae plant^{-1}). The result regarding the abundance of *A. craccivora* has shown that their population was maximum in farmers' practice (9.32 aphids plant^{-1}) which was followed by IPM module of T_1 (5.94 aphids plant^{1}) and T_2 (4.68 aphids plant^{1}). Minimal aphid population was recorded in T_3 (1.93 aphids plant^{-1}) and significantly differed from others. So, all of the approaches in the IPM modules helped to reduce the insect pest population compared to farmers' practice.

The outcomes of our investigation are in agreement with Zehnder *et al.* (1995) who reported that IPM program dramatically reduced the insect pest infestation and also the number of spraying operation in tomato crop as compare to conventional pest management practices. The current findings are supported by Rouf and Sardar (2011) in whose study neem extract was reported suitable to control legume pod borer in country bean. Analogously, Schmutterer (1990) and Dubey *et al.* (1991) reported NSKE as a good protectant for pulses due to their anti-feedant characters against pod borer. Praveen (2000) opined that bio-intensive integrated modules were very effective to reduce the pod borer population. According to Srinivasa *et al.* (1999), botanical pesticides were the most valuable component of IPM strategies. The results of our study are obtained ample support from the findings of Singh *et al.* (2008) and Maurya *et al.* (2016) who reported Rynaxypyr (i.e. Chlorantraniliprole) was the most effective insecticide against pod borers of pigeon pea while, according to Keval *et al.* (2018), Indoxacarb to be the most effective insecticide against *Helicoverpa*. The findings of the current experiment can be compared with the results of Neharkar *et al.* (2018) who found that Rynaxypyr was more effective than Spinosad and Indoxacarb in reducing pod boring pests in pigeon pea. Our findings are in agreement with Raghuvanshi *et al.* (2014) who

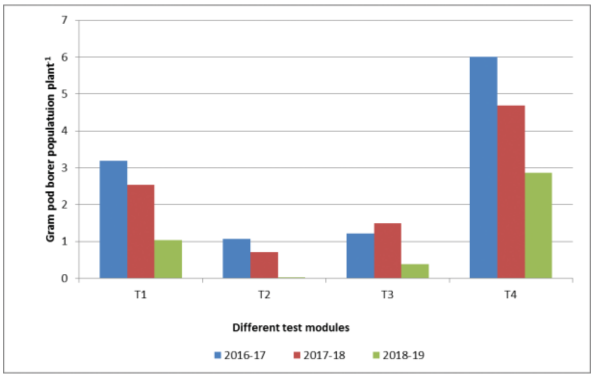

Fig. 1: Gram pod borer population in different test modules during experimental years

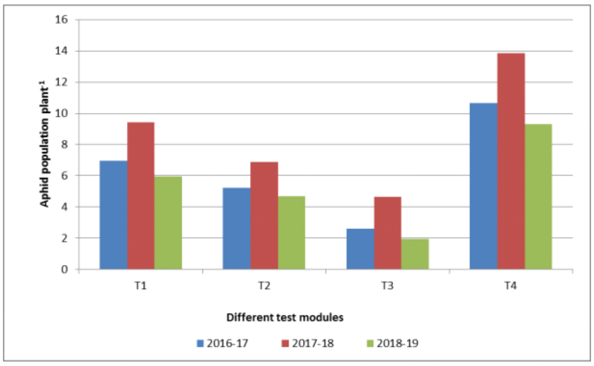

Fig. 2: Aphid population in different test modules during experimental years

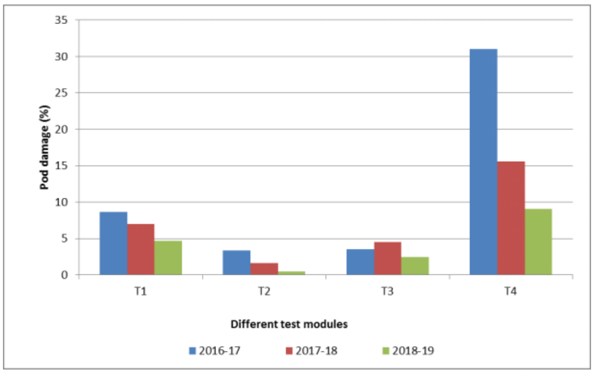

Fig. 3: Percent pod damage in different test modules during experimental years

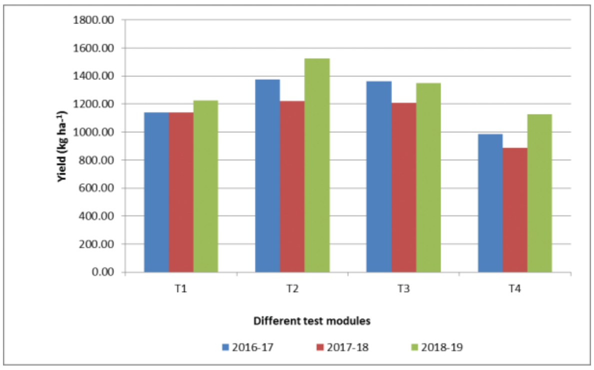

Fig. 4: Seed yield of field pea in different test modules during experimental years

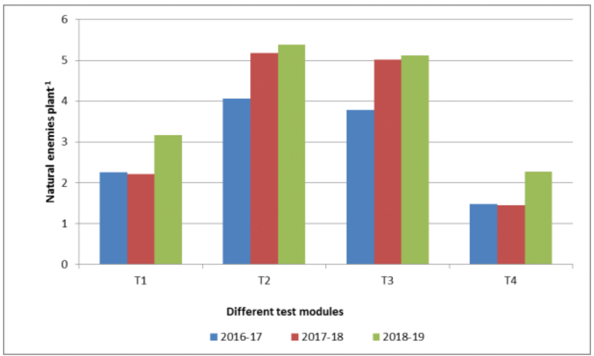

Fig. 5: Natural enemy population in different test modules during experimental years

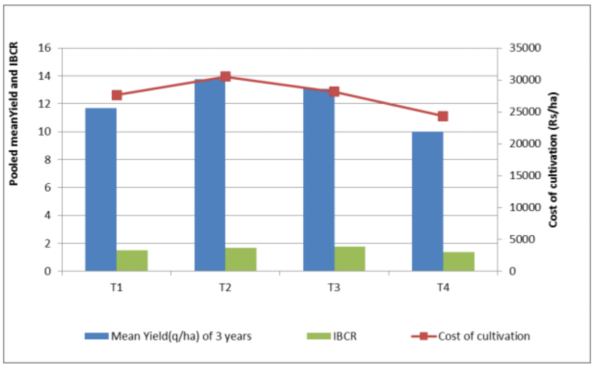

Fig. 6: Economics of different test modules

recorded effectiveness of Spinosad 45 SC against aphid population in soybean. The present findings are in tune with the reports of Panduranga *et al.* (2011) who reported that seed treatment with Imidacloprid enhanced the efficacy of integrated modules by reducing the occurrence of different sucking pests in mungbean. The above findings are in line with the results of Brar *et al.* (2002) who reported the lowest occurrence of *Helicoverpa* in IPM modules on cotton.

Impact of different test modules on per cent pod damage and yield

The effectiveness of different test packages to manage the pest population is reflected from the data of pod damage percentage and seed yield (Table 1, 2, 3 and Figure 3, 4). The results show that per cent pod damage in the three IPM modules were significantly lesser compared to farmers' practice. The highest per cent pod damage was noticed in T_4 (31.02%, 15.60%

and 9.08% during 1st, 2nd and 3rd year, respectively) which was followed by T_1 (8.64%, 7.00%, 4.73%), T_3 (3.56%, 4.53%, 2.48%) and T_2 (3.38%, 1.67%, 0.44%). The effect of IPM on seed yield revealed that field pea yield has increased significantly in all the IPM plots over farmers' practice. The highest yield of 1375.00 kg ha^{-1}, 1222.22 kg ha^{-1} and 1525.00 kg ha^{-1} during 1st, 2nd and 3rd year, respectively were obtained from T_2. The Module 3 i.e. T_3 with computed yield of 1361.11 kg ha^{-1}, 1208.33 kg ha^{-1}, 1350.00 kg ha^{-1} during 1st, 2nd and 3rd year, respectively was the next effective IPM module. The lowest yield was obtained from farmers' practice plot (986.11 kg ha^{-1}, 888.89 kg ha^{-1} and 1125.00 kg ha^{-1} during 1st, 2nd and 3rd year, respectively). The results regarding percent increase in yield over farmers practices' had revealed that by adopting IPM module 39.44%, 37.50% and 35.56% during 1st, 2nd and 3rd year, respectively more yield can be obtained in T_2 followed by T_3 (38.03%, 35.94%, 20.00%) and T_1 (15.49%, 28.13%, 8.89%). The outcomes are in accordance with Benagi *et al*. (2004) as well as Kavitha *et al*. (2013) who observed relatively less pod and seed damage in IPM module comparing to non IPM plots. Our findings are in agreement with Singh *et al*. (2003) who obtained higher yields in IPM plots as compared to control in pigeon pea.

Impact of different test modules on natural enemies

Significantly higher populations of natural enemies were observed in the plots followed the integrated practices than farmer's practice (Table 4 and Figure 5). The data regarding the population of natural enemies viz. coccinellid beetle reveal that their population was maximum in T_2 (4.06 beetles plant^{-1}, 5.17 beetles plant^{-1} and 5.38 beetles plant^{-1} during 2016-17, 2017-18 and 2018-19, respectively) followed by the IPM module of T_3 (3.78 beetles plant^{-1}, 5.02 beetles plant^{-1}, 5.12 beetles plant^{-1}) and T_1 (2.25 beetles plant^{-1}, 2.21 beetles plant^{-1}, 3.17 beetles plant^{-1}). Minimal population of coccinellid beetles (1.47 beetles plant^{-1}, 1.44 beetles plant^{-1}, 2.27 beetles plant^{-1}) was observed in conventional practice module (T_4) which may be due to the lethal effect of the Cypermethrin insecticide. The findings got support from Kumar *et al.* (2019) who found more coccinellid population in IPM module than farmers' practice in soybean. Similarly, Dhawan *et al.* (2009) recorded significantly higher population of friendly insects in IPM plots comparing to non-IPM plots. Ravi *et al.* (2008) reported that Spinosad was safe to natural enemies which agreeing with our results. However, according to Dinter *et al.* (2008), Chlorantraniliprole having encouraging eco-toxicological properties has less risk to lady beetles. The results of the present studies are partially comparable to Hetrick *et al.* (2005) who found that Indoxacarb is highly toxic to natural enemies of brassicaceae. The findings are in line with Peckman and Wilde (1993) who found 100% mortality of a coccinellid beetle, *Hippodamia convergens* by spraying Cypermethrin and hence, this insecticide was stated as toxic to the predator.

Impact of different test modules on economics

Evaluation of economics (Table 5 and Figure 6) clearly reveals that both the cost of inputs as well as net returns of the IPM plots were substantially higher than farmers' practice. Highest incremental benefit cost ratio (IBCR) obtained from Module 3 i.e. T_3 (1.78) and proved to be economical and effective IPM module though maximum net return obtained from T_2 with IBCR of 1.68. Minimum IBCR (1.39) was obtained from farmers' practice. This result is in tune with the findings of Singh and Singh (2015) who obtained maximum cost benefit ratio of 1:11.93 in IPM module as against 1:9.36 in farmer's practices in mungbean while, according to Cherry *et al.* (2000), cost of treatment is pre-requisite to select the treatment for pest control. Kavitha *et al.* (2013) also observed maximum cost benefit ratio in plots received integrated practices compared to conventional practices. Similarly, Chavan *et al.* (2003) obtained highest grain yield as well as highest net return from IPM modules. Kumar *et al.* (2019) reported slightly higher IBCR (1.66, 2.78 and 1.54) in different IPM plots of soybean than plots without having integrated practices.

CONCLUSION

The study confirms that integration of different control measures along with judicious use of less hazardous chemical pesticides in IPM programs are the best for suppressing the insect pest population in any situation particularly in case of field pea. In IPM program, each control measure contributes to reduce the pest density when applied in right time with an appropriate dose. It is advisable to use different pest management practices in holistic manner involving relatively less hazardous chemical insecticides with novel mode of action which minimizes the potential for resistance and resurgence development among the insect pests and also reduces the adverse impact of synthetic chemicals on beneficial arthropods.

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