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Incremental cost-benefit ratio of certain chemical and bio-pesticides against tomato fruit borer, *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) in tomato crop.

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ABSTRACT
An attempt was made to evaluate the efficacy of insecticides and biopesticides against fruit borer, Helicoverpa armigera infesting tomato at Student Instructional Farm of C.S.A.U.A &T., Kanpur, during Rabi season 2015-16. Among three insecticide viz., indoxacarb 14.5 SC, fipronil 5 SC, malathion 50 EC, and five biopesticides viz., spinosad 45 SC, Bacillus turingiensis var. kurstaki, HaNPV, neemarin and Metarrhizium anisopliae (Metschn.). All the insecticides significantly increased the yield of marketable fruits over control. The maximum yield was recorded in indoxacarb 14.5 SC @ 0.5 ml/lit (180 q/ha.) and fipronil 5 SC @ 1.0ml/lit. (172.50 q/ha), respectively. Among bio-pesticides, spinosad 45 SC @ 0.20ml/lit. and B. t. var. kurstaki @ 1.5gm/lit. with highest fruit yield of 155.65 q/ha and 148.25 q/ha respectively, were recorded. The best incremental cost benefit ratio was obtained with Indoxacarb 14.5 SC (1:14.73) and among biopesticides, Bt. var. kurstaki (1:11.57).
Key words: *Helicoverpa armigera, Indoxacarb, Spinosad, B. thuringiensis HaNPV and Tomato.*

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the important and remunerative vegetable crops grown around the world for fresh market and processing. The production and productivity of the crop is greatly hampered by the fruit borer, *Helicoverpa armigera* (Hübner). This is a key pest as it attacks the cashable part of the plant *i.e*. fruits and makes them unfit for human consumption causing considerable crop loss leading up to 55 per cent [11]. It has been estimated that the crops worth Rs.1000 crore are lost annually by this pest [5]. Chemical insecticides are generally preferred for the control of pest due to their easy availability and applicability, but their excessive and indiscriminate use has resulted in plethora of problems e.g. resurgence of minor insect pests, insecticidal resistance in insects, mortality of natural enemies and non target species and pesticide residue in harvested produce leading to various health hazards, besides the increased cost of cultivation per unit area. To overcome these problems, it has now become imperative to select safer insecticides that should protect the crop and keep the pest population below injury level. Hence, attempts were made to evaluate the efficacy of different chemical and bio-pesticides for the sustainable management of *H. armigera* on tomato. Therefore, in order to design a superior pest management model for the crop the present research study was undertaken to know the impact of certain chemical and bio-pesticides such as indoxacarb 14.5 SC, fipronil 5 SC, malathion 50 EC., and biopesticides viz., spinosad 45 SC, *Bacillus turingiensis var. kurstaki* , HaNPV, neemarin and *Metarrhizium anisopliae* against larvae of *H. armigera* to examine its impact on yield increase in tomato. Thereafter, Incremental Cost-Benefit Ratio (ICBR) of various sole and treatment combinations were obtained to find out the best economical application.

MATERIAL AND METHODS

The field experiment was conducted during Rabi seasons of 2015 and 2016. Seedlings of tomato variety Azad T-5 were transplanted in 3 x 2 m^2 plots with a spacing of 60 x 40 cm along with recommended standard agronomical practices except crop protection measures.

Insecticides used: Active ingredients and the respective formulated products used in this study were three chemical insecticide viz., T_1= Indoxacarb 14.5SC (0.50 ml/lit.), T_2=Fipronil 5SC (1.0 ml/lit.), T_3= Malathion 50EC (1.0 ml/lit.) and five bio-pesticides T_4= Spinosad 45SC (0.20 ml/lit.), T_5= *B. thuringiensis var kurstaki* (1.5 gm/lit.), T_6=HaNPV (1.0 ml/lit.), T_7=Neemarin 1500ppm (4.0 ml/lit.), T_8=*Metarrhizium anisopliae* (4.0 ml/lit.) and T_9= Control.

Preparation of insecticidal formulations:

From stock solution required concentrations of chemical and bio-pesticides were prepared. For preparing various concentrations, the required amount of insecticides was weighed on a digital electronic balance and indoxacarb, fipronil, malathion, spinosad, *Ha*NPV and neemarin were measured with the help of pipette (of 0.1ml capacity); and were dissolved in tap water and thereafter homogenous mixture was prepared by stirring the solution with a glass rod.

$$\textbf{Amount insecticide} = \frac{\text{concentration required per cent} \times \text{volume required (lit.)}}{\text{cocentration of toxicant in insecticide formulation}}$$

Determination of fruit yield: Upon maturity of the fruit, yield in different treatments were obtained separately by harvesting fruits from selected plants from respective plots along with untreated control. Fruit yield was calculated under different plots of a treatment as per formula suggested by Chejara [2]:-

$$\textbf{Yield (kg/ha)} = \frac{\text{Factor x Fruit Yield (kg)}}{\text{Number of Plot}}$$

$$\textbf{Where, Factor} = \frac{10000}{\text{Plot Size (sq.m.)}}$$

The increase in fruit yield was calculated as yield increase in treated plots compared to untreated plots as follows:

$$\textit{Per cent increased yield} = \frac{\textit{Increase yield in treated plot}}{\text{yeild in untyreated plot}} \times 100$$

Cost-Benefit analysis of bio-pesticide treatments: Cost of insecticide (Rs/ha): Insecticides were purchased from local market and the cost of insecticide was obtained by multiplying total quantity (kg/lit.) of respective pesticide required (for per hectare application) with the prevalent market price (Rs.) for per lit./kg of respective pesticide.

Laborer Wages (Rs/ha): Two laborers were considered sufficient for spraying in a day over one hectare crop @ prevailing local market rate of Rs. 200.00/day/labor.

Sprayer hiring charges (Rs/ha): The hire charge of power sprayer was considered as Rs.100.00 per hectare (including the petrol fuel cost) for respective treatments.

Cost of treatment (Rs/ha): Cost of insecticide, laborer wages and sprayer hiring charges were summed up to work out the cost of respective treatment.

Additional yield (Q/ha): This was obtained by subtracting the values of control yield from total fruit yield of a respective treatment.

Additional income (Rs./ha): It was calculated by multiplying the additional yield over the untreated control with prevailing minimum price (@Rs.1500/q during February 2016) of tomato fruit at local market (Kanpur, Uttar Pradesh).

Net return (Rs/ha): This was calculated separately by subtracting the cost of treatment from additional income of respective treatment.

Incremental Cost-Benefit ratio: This was calculated separately for each treatment as per following formulae suggested by Chejara [2]:

$$\textbf{Incremental Cost-benefit ratio} = \frac{\text{Net Return}}{\text{Cost of Treatment}}$$

RESULTS AND DISCUSSION

Fruit yield:

The overall efficacy of insecticides evaluated against marketable fruit yield of tomato among different treatments ranged from 122.35 to 180.00 q ha^{-1} (Table 1). The highest marketable yield of 180.00q ha^{-1}

was recorded in case of indoxacarb 14.5 SC followed by fipronil 5 SC and were as in bio-pesticides maximum fruit yield was recorded from the plots treated with spinosad 45 SC (155.65 q ha^{-1}) and *B. thuringiensis* (148.25 q ha^{-1}) followed by *Ha*NPV (137.00 q ha^{-1}). Yield of these treatments was significantly higher than the all other insecticides and superior to that of control (110.25 q ha^{-1}). The maximum percentage increase in yield over control was recorded from indoxacarb14.5 SC (63.26%) followed by fipronil 5 SC (56.46%), respectively. Whereas in bio-pesticides maximum per cent increase in yield was obtained from spinosad 45 SC (41.17%) followed by *B. thuringiensis var. kusustaki* (34.46%) and lowest percentage increase in yield was recorded from *M. anisopliae* (10.97%) but superior over control. The result of present investigation matched with results of Wagh *et al.* [15] effect of indoxacarb (60 and 70 g a.i. /ha) against *H. armigera* in tomato, yielded the highest yield of marketable fruits 29.16 and 29.50 tons/ha, respectively. Similar results obtained by Mahakalkar**,** *et al.* [7] the highest fruit yield was obtained by combination treatment of HaNPV and *B. thuringiensis* (16.92 t/ha) followed alternate spraying of with *B. thuringiensis and* HaNPV. Whereas, Chavan, *et al*. [1] reported that Spraying of *B. thuringiensis* @ 1kg/ha and azadirachtin 3000 ppm @ 2.5 lit./ha at 45 and 65 days after transplanting showed maximum efficacy against *H. armigera*.

Table no. 1: Impact of insecticidal treatments on tomato fruit yield

Sl. No.	Treatments	Mean weight of harvested marketable fruits (kg / plot)			Total yield (kg / plot)	Mean yield (Q / ha)	% yield increase over control
		1st pick	2nd pick	3rd pick			
1	Indoxacarb14.5SC	8.05	15.50	13.00	37.05	180.00	63.26
2	Fipronil 5SC	7.50	14.50	12.75	34.75	172.50	56.46
3	Malathion 50EC	7.00	12.00	10.95	29.95	160.45	45.53
4	Spinosad 45SC	6.50	10.80	8.50	25.80	155.65	41.17
5	*B. thuringiensis var. krustaki*	5.75	9.50	7.85	23.10	148.25	34.46
6	HaNPV	5.25	8.75	7.00	20.75	137.00	24.26
7	Neemarin	4.85	8.00	6.75	19.60	130.25	18.14
8	*M. anisopliae*	4.00	8.50	6.45	18.95	122.35	10.97
9	Control	3.25	4.00	4.75	12.00	110.25	0
	SE± (d)	1.12	1.17	1.01	1.71	13.94	
	CD at 5%	2.42	2.51	2.16	3.68	29.90	

Comparative economics of insecticides and bio-pesticides against, *H. armigera*

The data presented in Table 2 indicated that maximum net profit was obtained from chemical insecticides such as indoxacarb 14.5 SC (262200 Rs/ha) followed by fipronil 5SC (262200 Rs/ha) and whereas in bio-pesticides spinosad 45 SC (227550 Rs/ha) followed by *B. thuringiensisvar. krustaki* (217575 Rs/ha), respectively. The minimum net profit of 238452 Rs/ha was obtained from malathion 50 EC whereas in bio-pesticides HaNPV (202200 Rs/ha), neemarin (192495 Rs/ha) and (178233 Rs/ha) in *M. anisopliae*, respectively but they are superior over control. The results of present investigation agreed with Singh *et al.* [13] the net profit of Rs. 275645 was found in indoxacarb which was at par to the acephate. However, the net profit of Rs. 214139 by Dhaka *et al.* [3]] and Rs. 221288 by Kumar and Devi [6] are agreement with the present results. The net profit of Rs. 200070 and Rs. 201026 reported by Moorthy *et al.* [8] and Kumar and Devi [6] respectively, from the treatment of spinosad are in agreement with the results of present studies. Roopa and Kumar [10] reported net profit of Rs. 274461 from indoxacarb, Rs. 240661 from spinosad and Rs. 201491 from chlorantraniliprole support the present results.

Incremental Cost-benefit ratio (ICBR):

The highest incremental cost benefit ratio (ICBR) of 1:14.73 was computed in chemical insecticides i.e., indoxacarb 1:14.5 SC followed by 1:13.88 in fipronil 5 SC and 1:12.93 in malathion 50 EC. Among bio-pesticides maximum ratio was obtained from *B. thuringiensis var. kurstaki* (1:11.57) followed by spinosad 45 SC (1:11.42). The minimum incremental cost benefit ratio 1:13.21, 1:10.76 and 1:0.48 was obtained in HaNPV, neemarin and *M. anisopliae.* These findings agreed with the observation of Sherzad and Kumar [12], reported that chemical insecticides, indoxacarb 14.5 SC, spinosad 45SC and imidacloprid 200 SL were most effective. The best cost benefit ratio was obtained with indoxacarb 14.5 SC (1:11.95). Contrary to the present finding, Sreekanth *et al.* [14] reported the highest incremental cost benefit ratio was computed from chlorantraniliprole followed by indoxacarb(1:3.67), abamectin (1:3.13) and spinosad (1:2.97). Jat and Ameta [4] reported the highest incremental cost benefit ratio of 12.075 in spinosad also does not support the present results. Rahman *et al.* [9] obtained the highest incremental cost benefit ratio (1:5.30) from alternate spray of *Ha*NPV and *B. thuringiensis* followed by alone spray of *Ha*NPV (4.46) and *B. thuringiensis* (1:3.37). The difference in incremental cost benefit ratio may be due to the high difference in the cost of insecticides and quantity of yield produced.

Table 2. Effect of chemical and microbial insecticides on net income and marginal benefit cost ratio in *H. armigera*.

Treatments	Dose / Ha (ml or gm)	No of sprays	Average yield (Q/Ha)	Gross return (Rs)	Management cost (Labor + insecticides) (Rs/Ha)	Net income (Rs/ha)	Value of increased yield over control (Rs/Ha)	C:B Ratio
Indoxacarb 14.5 SC	500 ml	3	180.00	270000	17800.0	262200	96825	1:14.73
Fipronil 5SL	800 ml	3	172.50	258750	17160.0	253590	88215	1:13.88
Malathion 50EC	1.25 lit	3	160.45	240675	18421.0	238254	72879	1:12.93
Spinosad 45SC	125 ml	3	155.65	233475	19925.0	227550	62175	1:11.42
B. thuringiensis	1.0 kg	3	148.25	222375	18800.0	217575	52200	1:11.57
HaNPV	250 LE	3	137.00	205500	15300.0	202200	36825	1:13.21
Neemarin	2.25 lit	3	130.25	195375	17880.0	192495	27120	1:10.76
M.anisopliae	2.66 Kg	3	122.35	183525	16992.0	178233	12858	1:10.48
Control	0	0	110.25	165375	0	165375	-	-

Tomato 1 q = 1500/- Rs and 1 kg = 15.00 Rs
Spraying charge = 200 Rs/ Ha

CONCLUSION

The experiment on efficacy of different insecticidal and bio-pesticide treatments revealed that indoxacarb 14.5SC was found most effective and it shown the highest ICBR against fruit borer followed by fipronil5 SC and resulted higher fruit yield, while in bio-pesticides spinosad 45 SC and *B. thuringiensis* proved very effective followed by HaNPV and neemarin and *M. anisopliae* least effective compare to rest of treatments. Therefore, keeping in view its cost-efficacy and eco-friendly nature, the same is recommended to farmers of Kanpur (India) for its suitable incorporation towards integrated management of *Helicoverpa armigera* in tomato.

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