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The impact of bio-pesticides, microbial and botanicals application on tomato (*Lycopersicon esculentum*) yield: Calculating the incremental benefit-cost ratio for managing *Helicoverpa armigera* infestation

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Abstract
The investigation was carried out during Rabi season in 2021–2022, and 2022–2023, at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, in the Student Instructional Farm (SIF), geographically, the district of Kanpur Nagar is located between latitude 260 29' north and longitude 79031' and 80034' east. It is in the subtropical zone. It is located 125.9 metres above the gangetic alluvial in the centre of Uttar Pradesh. This experiment was conducted to study on the population dynamics of fruit borer *Helicoverpa armigera* Hubner on tomato, *Lycopersicon esculentum* Mill. "Of insect-pest infesting tomato crops. It's showed that in pooled data the spraying of Spinosad 45% SC provided highest yield 210.11 q/ha and 75.59% increased yield over control as compared to all other treatments. The spraying of B.T., HANPV+NSKE and HANPV provide better yield i.e. 185.46 q/ha, 178.60 q/ha and 171.66 respectively, with 54.40 percent, 48.69 and 42.92 percent increase over control, respectively. The application of *Beauveria bassiana* provide 167.15 q/ha and 39.17 percent increased yield. The spraying of Neem oil also provided 161.49 q/ha with 39.16 percent yield. The spraying of NSKE also provided 155.84 q/ha with 29.74 percent yield. The application of Tobacco 5% gave poorest yield i.e. 147.48 q/ha with 22.78% minimum increased yield in the present investigation as evident from Table. The poorest yield provided by control 120.11 q/ha.

Keywords: Technology, *Beauveria bassiana*, spraying

Introduction
Tomato, *Solanum lycopersicum* (L.) is one of the most important commercial vegetable crop grown all over the world and occupies the third position among vegetables in area and production in the world (Bhavana and Nagar, 2019) [9] It is popularly known as Wolf apple, Love of apple or *Vilayati baingan*. It ranks third largest vegetable crop after potato and sweet potato, but it top in the list of canned vegetables. It can be used fresh in salad, curries or by bi-product like *chutney*, pickle, soups, ketchup, sauce, powder, *purees* and as a whole *etc*. Tomato is the most widely eaten vegetable, ranking first as a processing vegetable and second in terms of production after potato in the world. Nutritionally, it serves as a source of vitamins A, B, C, and D and minerals such as calcium, phosphorus, and iron. It is consumed in fresh or processed forms. However, the national average yield of tomatoes of countries such as China (59.4 tons ha^{-1}), India (24.6 tons ha^{-1}), the USA (96.8 tons ha^{-1}), Turkey (68.8 tons ha^{-1}), and Egypt (40.9 tons ha^{-1}) (Mengistie *et al*., 2022) [8].11 The important insect pest of tomato is fruit borer, *Helicoverpa armigera* (Hubner); whitefly, *Bemisia tabaci* (Gen.); jassids, *Amrasca devastans* (Ishida); leaf miner, *Liriomyza trifolii* (Blanchard); potato aphid, *Myzus persicae* (Thomas) and hadda beetle, Epilachna dodecastigma (Widemann). But in India fruit borer is one of the most important pests of tomato, limiting production and market value of crop produce. The fruit borer, *Helicoverpa armigera* (Hubner) is the most destructive pest of tomato in India, which is commonly known as gram pod borer, American bollworm and fruit borer (The damage caused

by insect-pests is one of the main constraints which limit the production of tomato Among the insect pests, tomato fruit borer is Meena and Raju, 2014) [6]. Highly destructive pest causing serious damage and responsible for significant yield loss up to 55 percent (Talekar *et al.*, 2006) [2]. It also caused 40-50 percent damage to the tomato crop (Pareek and Bhargava, 2003) [3]. The fruit borer, *Helicoverpa armigera* (Hubner) has been reported to cause serious losses throughout its range, in particular to tomato it has been found to cause a yield loss of 35-37.79% fruit. (Biswas *et al*., 2022) [10].

Methods and Materials

The experiment was conducted at the Student Instruction Farm (SIF) of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, during the Rabi seasons of 2021-22 and 2022-23. The tomato crop, specifically the Azad T6 cultivar, was initially nursery in the Department of Vegetable Science at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Transplanting of the seedlings occurred on November 3, 2021, and November 1, 2022, for both years of the study. Geographically, Kanpur Nagar district is situated in the subtropical zone, positioned at a latitude of approximately 26°29' north and a longitude ranging from 79°31' to 80°34' east. The district is situated at an elevation of approximately 125.9 meters above the Gangetic alluvial plains, marking its central location within the state of Uttar Pradesh. For the current experiment, tomato seedlings of the Azad T_{-6} variety, aged 31 days, were transplanted into the field. Both experiments were conducted using a Completely Randomized Block Design (CRBD). The first experiment consisted of nine treatments, which included one control, while the second experiment also included nine treatments with a control group, and both experiments were replicated three times. The tomato seedlings were transplanted into plots measuring 3×2.5 square meters, with a spacing of 60×45 centimeters between each plant. All recommended agronomical practices were meticulously followed to ensure optimal crop growth. Each planting spot received a single seedling, and a light irrigation was administered immediately after transplanting the seedlings. Subsequently, only the healthy plants were allowed to thrive, while weaker and deceased plants were replaced through gap-filling procedures one week after transplantation, aimed at maximizing field yield.

The tomato fruit were regularly removed from each plot when they were edible and their weight was recorded per plot. After two months after transplanting, the first picking was done, and then another 7 days later. To determine the yield in q/ha, the total picking yield was pooled. Incremental cost benefit ratio was calculated by Fruit yield of different treatments from both the experiments and additional yield was calculated with prevailing market price at the time or cost benefit ratio was calculated on the basis of net income obtained from additional yield.

Cost-Benefit analysis of treatments: Insecticide costs per hectare were calculated based on the local market prices. The cost of each insecticide was determined by multiplying the total quantity (in kilograms or liters) required for one-hectare application with the prevailing market price per kilogram or liter of that specific pesticide in Indian Rupees (Rs)."

Laborer Wages (Rs/ha): Two laborers were determined to be adequate for daily spraying on a one-hectare crop at the current local market wage rate. The cost of hiring the power sprayer, including the cost of petrol fuel, was set at the prevailing local market rate per hectare for each specific treatment. To calculate the cost of each treatment, we added together the expenses for insecticide, laborer wages, and sprayer hiring charges.

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

$$\text{IBCR} = \frac{\text{Returns in treatment (Rs/ha)}}{\text{Returns in control (Rs/ha) + Cost of insecticides \& labour (Rs/ha)}}$$

Results and Discussion

Effect of different bio-pesticides, microbial and botanicals on yield of tomato 2021-22

Table no 1 indicated that the spraying of Spinosad 45% SC provided highest yield 213.02 q/ha and 75.44% increased yield over control as compared to all other treatments. The spraying of B.T., HANPV+NSKE and HANPV also provided better yield i.e. 183.46 q/ha, 176.76 q/ha and 171.91 q/ha respectively, with 51.09, 45.57 and 41.58 percent increase over control, respectively. The application of *Beauveria bassiana* provide 164.67 q/ha and 35.62 percent increased yield. The spraying of Neem oil also provided 159.16 q/ha with 31.08 percent yield. The spraying of NSKE also provided 153.82 q/ha with 26.68 percent yield. The application of Tobacco 5% gave poorest yield i.e. 149.24 q/ha with 22.91% minimum increased yield in the present investigation as evident from table no 1.

Effect of different bio-pesticides, microbial and botanicals on yield of tomato Yield 2022-23

It is clear from Table no 2 every treatments give higher yield an untreated plot (control). The spraying of Spinosad 45% SC provided highest yield 208.80 q/ha and 75.75% increased yield over control as compared to all other treatments. The spraying of B.T., HANPV+NSKE and HANPV provide better higher yield i.e. 187.47 q/ha, 180.44 q/ha and 171.42 q/ha respectively, with 57.80 percent, 51.88 and 44.29 percent Increase over control, respectively. The application of *Beauveria bassiana* provide 164.67 q/ha and 42.79 percent increased yield. The spraying of Neem oil also provided 163.82 q/ha with 37.89 percent yield. The spraying of NSKE also provided 157.86 q/ha with 32.87 percent yield. The application of Tobacco 5% gave yield i.e. 145.73 q/ha with 22.66% minimum increased yield in the present investigation as evident from Table. The poorest yield obtained from control I. e.118.80 q/ha.

Table 1: Effect of different bio-pesticides, microbial and botanicals on yield of tomato 2021-22. (Kg/plot)

Symbol	Treatments	I Pick (Kg/plot)	II Pick (Kg/plot)	III Pick (Kg/plot)	Tot al Yield (Kg/Plot)	Yield (Q/ha)	Yield over control (Q/ha)
T_1	HANPV+NSKE	3.21	4.63	5.42	13.26	176.76	55.34
T_2	Tobacco 5%	2.87	4.59	3.73	11.19	149.24	27.82
T_3	HANPV	3.15	5.44	4.30	12.89	171.91	50.49
T_4	Neem seed kernel extract	2.92	4.77	3.85	11.54	153.82	32.40
T_5	*Neem oil*	2.99	3.98	4.97	11.94	159.16	37.74
T_6	*Beauveria bassiana*	3.12	4.06	5.17	12.35	164.67	43.25
T_7	Spinosad 45%SC	4.66	5.99	5.33	15.98	213.02	91.6
T_8	*Bacillus thuringiensis*	3.29	5.88	4.58	13.76	183.46	62.04
T_9	Control	2.52	3.04	3.55	9.11	121.42	-
	SE(m)±	0.17	0.38	0.31	0.64	8.51	-
	SE(d)±	0.24	0.54	0.44	0.90	12.03	-
	C.D. at 5%	0.51	1.15	0.95	1.93	25.73	-
	C.V. (%)	9.08	14.01	11.91	8.88	8.88	-

Table 2: Effect of different bio-pesticides, microbial and botanicals on yield of tomato 2022-23. (Kg/plot)

Symbol	Treatments	I Pick (Kg/plot)	II Pick (Kg/plot)	III Pick (Kg/plot)	Total Yield (Kg/Plot)	Yield (Q/ha)	Yield over control (Q/ha)
T_1	HANPV+NSKE	3.26	4.51	5.76	13.53	180.44	61.64
T_2	Tobacco 5%	2.82	3.65	4.47	10.93	145.73	26.93
T_3	HANPV	2.97	5.53	4.36	12.86	171.42	52.56
T_4	Neem seed kernel extract	2.97	4.92	3.94	11.84	157.86	39.06
T_5	*Neem oil*	3.05	5.14	4.10	12.29	163.82	45.02
T_6	*Beauveria bassiana*	2.36	6.12	4.24	12.72	169.64	50.84
T_7	Spinosad 45%SC	3.61	6.82	5.22	15.66	208.80	90.00
T_8	*Bacillus thuringiensis*	4.35	5.03	4.69	14.06	187.47	68.67
T_9	Control	2.48	3.45	2.97	8.91	118.80	-
	SE(m)±	0.23	0.31	0.37	0.50	6.72	-
	SE(d)±	0.33	0.44	0.52	0.71	9.50	-
	C.D. at 5%	0.70	0.94	1.11	1.52	20.32	-
	C.V. (%)	12.94	10.76	14.34	6.96	6.96	-

Effect of different bio-pesticides, microbial and botanicals on Pooled Yield Data of tomato 2021-22 and 2022-23

Table no 3 indicated that every treatments give higher yield an untreated plot (control). The spraying of Spinosad 45% SC provided highest yield 210.11 q/ha and 75.59% increased yield over control as compared to all other treatments. The spraying of B.T., HANPV+NSKE and HANPV provide better yield i.e. 185.46 q/ha, 178.60 q/ha and 171.66 respectively, with 54.40 percent, 48.69 and 42.92 percent increase over control, respectively. The application of *Beauveria bassiana* provide 167.15 q/ha and 39.17 percent increased yield. The spraying of Neem oil also provided 161.49 q/ha with 39.16 percent yield. The spraying of NSKE also provided 155.84 q/ha with 29.74 percent yield. The application of Tobacco 5% gave poorest yield i.e. 147.48 q/ha with 22.78% minimum increased yield in the present investigation as evident from Table. The poorest yield provided by control 120.11 q/ha.

Table 3: Effect of different bio-pesticides, microbial and botanicals on Pooled Yield Data of tomato 2021-22 and 2022-23

Symbol	Treatments	Pooled data 2021- 22 to 2022-23					
		I PICK (Kg/Plot)	II PICK (Kg/Plot)	III PICK (Kg/Plot)	Total Yield (Kg/Plot)	Yield (Q/ha)	Yield over control (Q/ha)
T_1	HANPV+NSKE	3.23	4.57	5.59	13.39	178.60	48.69
T_2	Tobacco 5%	2.84	4.16	4.10	11.09	147.48	22.78
T_3	HANPV	3.06	5.48	4.33	12.87	171.66	42.91
T_4	Neem seed kernel extract	2.94	4.38	3.89	11.69	155.84	29.74
T_5	Neem oil	3.02	5.05	4.53	12.11	161.49	34.45
T_6	Beauveria bassiana	2.74	5.09	4.70	12.53	167.15	39.16
T_7	Spinosad 45%SC	4.13	6.40	5.27	15.82	210.91	75.59
T_8	*Bacillus thuringiensis*	3.82	4.16	4.63	13.91	185.46	54.40
T_9	Control	2.50	3.24	3.26	9.01	120.11	-
	SE. m.±	0.06	0.12	0.09	0.29	3.82	-
	S.E. (D)±	0.08	0.17	0.13	0.41	5.40	-
	CD at 5%	0.18	0.37	0.28	0.88	11.55	-
	CV (%)	3.27	4.46	3.62	4.03	3.97	-

Effect of different bio-pesticides, microbial and botanicals in Computation of incremental benefit cost ratio (IBCR) for management of *Helicoverpa armigera*. 2021-22

The data presented in table no 4 indicated that the highest benefit cost ratio was recorded in Spinosad 45% SC i.e. 1:32.59, which was superior over all treatments. The mean yield of tomato from Spinosad 45% SC was 213.02 q. /ha. And increased yield over control was 91.6 q. /ha. & net profit obtained from the increased yield was 133310 Rs/ha. The second prominent treatment after Spinosad 45% SC was B.T.

that produce mean yield of tomato i.e.183.46 q/ha. With incremental benefit cost ratio of 1:15.89. The intermediary treatments HANPV + NSKE and HANPV were recorded which provided mean yield of tomato i.e. 176.76 q. /ha. and 171.91 the IBCR were 1: 4.40 and which was comparatively superior with other treatments like Beauveria bassiana, Neem oil and NSKE with mean yield of tomato to the tune of 164.67, 159.16, &153.82 q./ha., respectively, and IBCR ratio was 1:16.30, 1:11.09, and 1:2.17 respectively. The better mean yield of tomato crop was obtained from the plot treated with Tobacco 5% i.e. 149.24 q. /ha., with IBCR ratio of 1:7.69 was noticed however, it was superior over control in which mean yield of tomato i.e. 121.42 q./ha. Was recorded. The lowest yield provided by control 121.42 q. /ha.

Table 4: Effect of different bio-pesticides, microbial and botanicals in Computation of incremental benefit cost ratio (IBCR) for management of *Helicoverpa armigera*. 2022-23

T.N	Treatment and dose	Dose of insecticide	Amount of insecticide On hac basis	Cost of insecticide (Rs/lit/kg)	Cost of insecticide Rs/hac	Labur cost	Total expenditure (Rs/hac)	Total yield (Q/hac)	Increased yield over control (Q/h)	Gross income	Net income over control	Net income	ICBR
1	HANPV+NSKE	.2 ml/lit+ 50 gm/lit	120 ml + 30 kg/ha	420 lit+450/kg	13550	1800	15350	176.76	55.34	265140	83010	67660	1:4.40
2	Tobacco 5%	100 gm/lit	60 kg/ha	50/kg	3000	1800	4800	149.24	27.82	223860	41730	36930	1:7.69
3	HANPV	.2 ml/lit	120 ml/ha	420/lit	50	1800	1850	171.91	50.49	257865	75735	73885	1:39.93
4	Neem seed kernel extract 5%	50 gm/lit	30 kg/ha	450/kg	13500	1800	15300	153.82	32.4	230730	48600	33300	1:2.17
5	Neem oil	5 ml/lit	3 lit/ha	320/lit	2880	1800	4680	159.16	37.74	238740	56610	51930	1:11.09
6	*Beauveria bassiana*	2 gm/lit	3 kg/ha	650/kg	1950	1800	3750	164.67	43.25	247005	64875	61125	1:16.30
7	Spinosad 45% SC	.4 ml/lit	240 ml/hac	9545/lit	2290	1800	4090	213.02	91.6	319530	137400	133310	1:32.59
8	*Bacillus thuringiensis*	1 kg/hac	1 kg/ha	1236/kg	1236	1800	3036	183.46	62.04	275190	93060	90024	1:15.89
	Control							121.42		182130			

Effect of different bio-pesticides, microbial and botanicals in Computation of incremental benefit cost ratio (IBCR) for management of *Helicoverpa armigera*. 2022-23

It is clear from the table no 5 that the highest incremental benefit cost ratio (IBCR) was recorded in Spinosad 45% SC i.e. 1:32.00, which was superior over all treatments. The mean yield of tomato from Spinosad 45% SC was 208.80 q. /ha. And increased yield over Control was 90.8 q. /ha. & net profit obtained from the increased yield was 130910 Rs/ha. The second prominent treatment after Spinosad 45% SC was B.T. (Dipel) that produce mean yield of tomato i.e.183.46 q/ha. With incremental benefit cost ratio (IBCR) of 1:32.92. The intermediary treatments HANPV + NSKE and HANPV were recorded which provided mean yield of tomato i.e. 180.44 q. /ha. And 171.42, the IBCR were 1: 5.02 and 1:41.6 which was comparatively superior with other treatments like Beauveria bassiana, Neem oil and NSKE with mean yield of tomato to the tune of 169.64, 163.82, &157.86 q./ha., respectively, and IBCR ratio was 1:19.33, 1:13.42, and 1:2.82 respectively. The lowest mean yield of tomato crop was obtained from the plot treated with Tobacco 5% i.e. 145.73 q. /ha., with IBCR ratio of 1:7.41 was noticed however, it was superior over control in which lowest mean yield of tomato i.e. 118.80 q./ha. Was recorded.

Table 5: Effect of different bio-pesticides, microbial and botanicals in Computation of incremental benefit cost ratio (IBCR) for management of *Helicoverpa armigera*.2022-23

T.N	Treatment and dose	Dose of insecticide	Amount of insecticide On hac basis	Cost of insecticide (Rs/lit/kg)	Cost of insecticide Rs/hac	Labur cost	Total expenditure (Rs/hac)	Total yield (Q/ha)	Increased Yield over control (Q/h)	Gross income	Net income over control	Net income	IBCR
1	HANPV+NSKE	.2 ml/lit+ 50 gm/lit	120 ml + 30 kg/ha	420 lit+450/kg	13550	1800	15350	180.44	61.64	270660	92460	77110	1:5.02
2	Tobacco 5%	100 gm/lit	60 kg/ha	50/kg	3000	1800	4800	145.73	26.93	218595	40395	35595	1:7.41
3	HANPV	.2 ml/lit	120 ml/ha	420/lit	50	1800	1850	171.42	52.56	257130	78930	77080	1:41.67
4	Neem seed kernel extract 5%	50 gm/lit	30 kg/ha	450/kg	13500	1800	15300	157.86	39.06	236790	58590	43290	1:2.82
5	Neem oil	5 ml/lit	3 lit/ha	320/lit	2880	1800	4680	163.82	44.84	245730	67530	62850	1:13.42
6	*Beauveria bassiana*	2 gm/lit	3 kg/ha	650/kg	1950	1800	3750	169.64	50.84	254460	76260	72510	1:19.33
7	Spinosad 45% SC	.4 ml/lit	240 ml/hac	9545/lit	2290	1800	4090	208.80	90.00	313200	135000	130910	1:32.00
8	*Bacillus thuringiensis*	1 kg/hac	1 kg/ha	1236/kg	1236	1800	3036	187.47	68.67	281205	103005	99969	1:32.92
	Control							118.80		178200			

The result and discussion supported by Jamir and Kumar (2022) [11] reported that the present investigation entitled, "Field efficacy and economics of some biopesticides against tomato fruit borer [*Helicoverpa armigera* (Hubner)]". Cultivar i.e. Pusa Ruby was conducted during November to March 2021-2022 at Central Research Farm of Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Prayagraj. When cost benefit ratio was worked out the best and most economical treatment was T_4 – Spinosad (1:8.84), followed by T_3 - Nisco Sixer plus (1:8.04), T_7 – HANPV (1:7.53), T_6 – *Bacillus thuringiensis* (1:6.51), T_5 – Beauveria bassiana (1:6.34), T_2-Nimbecidine (1:5.67) as compared to T_0-Control (1:4.58). B N *et al* (2018) [5] noticed that an attempt was made to evaluate the efficacy of insecticides and biopesticides against fruit borer, *Helicoverpa armiger* infesting tomato at Student Instructional Farm of C.S.A.U.A &T., Kanpur, during Rabi season 2015-16. The maximum yield was recorded in fipronil 5 SC @ 1.0 ml/lit. (172.50 q/ha), respectively. Among bio-pesticides, spinosad 45 SC @ 0.20 ml/lit. And B. t. var. kurstaki @ 1.5 gm/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).

Conclusion

Overall result on percent fruit infestation reduction and yield revealed that the Spinosad 45% SC gave best result performance by receiving minimum infested fruit of *H. armigera* giving highest yield of in 2021- 22 is 213.02 q/ha and 2022-23 is 208.80 q/ha. The next best treatments B.t., HaNPV + NSKE and HaNPV were 183.46 q/ha, 176.76 q/ha and 171.91 q/ha respectively give in 2021- 22 and 187.47 q/ha, 180.44 q/ha and 171.42 q/ha provide in 2022-23. However, the maximum IBCR, in 2021-22 (1:39.93) and in 2022-23 (1:41.67) was found in plot treated with HaNPV.

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