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Management of tomato fruit borer by incorporating newer and biorational insecticides

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Abstract
An attempt was made to evaluate nine newer and biorational insecticides against fruit borer, *Helicoverpa armigera* infesting Tomato at farm of Agricultural Research station, Swami Keshwanand Rajasthan Agricultural University, Bikaner, during the *rabi* season 2013-14. Among nine insecticides, indoxacarb 14.5 SC (0.01%) was found most effective against fruit borer followed by novaluron 10 EC (0.01%) and acephate 75 SP (0.037%). *Bacillus thuringiensis* 8L (0.012%) proved least effect followed by *Ha*NPV (250 LE/ha) and quinalphos 25 EC (0.02%).The treatments of chlorantraniliprole 18.5 SC (0.02%), abamectin 5 SG (0.01%) and spinosad 2.5 SC (0.01%) ranked in middle order of their efficacy. All the insecticides significantly increased the yield of marketable fruits over control. The maximum yield (265.20 q ha^{-1}) was recorded in indoxacarb followed by novaluan (262.85 q ha^{-1}) and acephate (258.22 q ha^{-1}). The minimum yield was recorded in *B. thuringiensis* (206.54 q ha^{-1}) followed by *Ha*NPV (213.24 q ha^{-1}).

Keywords: *H. armigera, tomato, indoxacarb, B. thuringiensis* and *Ha*NPV

1. 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 (Selvanarayanan, 2000) [1]. It has been estimated that the crops worth Rs.1000 crore are lost annually by this pest (Jayraj *et al.*1994) [2] 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 newer and biorational insecticides for the sustainable management of *H. armigera* on tomato.

2. Materials and Methods
The experiment was laid out in a Randomized Block Design with three replications. Each plot size was 3.6×2.0 m^2. The seed of tomato (Variety "RS-2") were sown in raised nursery beds in last week of October. The seedlings were transplanted in the experimental block after they attained a height of 15 cm with 8-10 leaves in the last week of November keeping row to row distance 60 cm and plant to plant distance 40 cm.
Field experiment was laid out in a randomized block design with nine treatments replicated three times. The insecticide treatments included indoxacarb 14.5 SC (0.01%), novaluron 10 EC (0.01%); acephate 75 SP (0.037%), chlorantraniliprole 18.5 SC (0.02%), abamectin 5 SG (0.01%), spinosad 2.5 SC (0.01%), *B. thuringiensis* 8L (0.012%) and HaNPV (250 LE/ha) along with an untreated control. Tomato variety 'RS-2' was grown in plot of size 3.6×2.0 m^2 at spacing of 60 × 40 with recommended package of practices. First spray was given after 9 weeks of transplanting of seedling and thereafter, repeated at 15 days intervals, in all two sprays were applied consecutively. The control plot was sprayed with water only. The population of tomato fruit borer and its damage (on per cent infestation of fruits on number

basis) were recorded at 3, 6, 9, 12 and 15 days after spray. The yield data was recorded at each picking and the mean fruit yield was computed on the basis of cumulative data of all picking. The economics of the treatments was worked out.

2.1 Statistical Analysis

The population data of *H. armigera* obtained was subjected for the conversion into per cent reduction using Henderson and Tilton (1952) [3] formula as under:

$$\text{Per cent reduction in population} = 100\left[1-\frac{T_a \times C_b}{T_b \times C_a}\right]$$

Where,
T_a = Number of insects after treatment
T_b = Number of insects before treatment
C_a = Number of insects in untreated check after treatment
C_b = Number of insects in untreated check before treatment.

The reduction percentage figures were transferred into arc sine values and subjected to analysis of variance. The data on percentage infestation of tomato fruits by borer was calculated at each picking by counting damage and healthy fruits in each spray application. The mean per cent fruit damage was calculated using formula:

$$\textit{Mean fruit damage (\%)} = \frac{\textit{Number of damaged fruits}}{\textit{Total number of fruits}} \times 100$$

The economics of different treatments was calculated by taking into consideration the cost of application of different treatments and prevailing market price of tomato. The total marketable fruit yields obtained from all plots were computed on hectare basis. The increase in fruit yield was calculated as yield increase in treated plots compared to untreated plots as follows:

$$\textit{Per cent increased yield} = \frac{\textit{Increase yield in treated plot}}{\textit{Yield in untreated plot}} \times 100$$

Incremental cost benefit ratio was calculated by deducting the cost of insecticidal treatments from price of increased yield over control by using following formula:

$$\text{B:C ratio over control} = \frac{\text{Returns in treatment (Rs./ha)}}{\text{Returns in control (Rs./ha)} + \text{Cost of insecticides and labour (Rs./ha)}}$$

3. Results

The overall efficacy of insecticides evaluated against fruit borer in respect of population reduction after two sprays (Table 1 & Figure 1) revealed that indoxacarb (63.37%) proved most effective insecticide followed by novaluron (61.85%), acephate (59.65%) and chlorantraniliprole (56.99%). Whereas, abamectin, spinosad and quinalphos registered 53.66, 50.46 and 48.46 per cent population reduction, respectively ranked in middle order of their efficacy. *Ha*NPV (44.81%) and *B. thuringiensis* (44.67%) proved as least effective insecticides and both are comparable to the quinalphos.

The pooled mean data of overall efficacy of different insecticides against fruit borer in respect of per cent fruit damage on number basis at all intervals after two sprays (Table 2 & Figure 2) revealed that indoxacarb (9.27%) was found most effective insecticide followed by novaluron (10.33%) and acephate (11.01%). These three insecticides were statistically at par to each other. However, novaluron and acephate were comparable to chlorantraniliprole. *B. thuringiensis* was found least effective insecticide with 19.13 per cent fruit damage followed by *Ha*NPV (18.56%) and quinalphos (17.06%). The insecticides chlorantraniliprole (12.47%), abamectin (13.67%) and spinosad (14.12%) existed in middle order of efficacy and were statistically at par to each other. All nine insecticides reported superior to control (36.08%) in respect of per cent fruit damage on number basis by fruit borer.

The marketable yield of tomato among different treatments ranged from 181.56 to 265.20 q ha^{-1} (Table 3 & Figure 3). The highest marketable yield of 265.20 q ha^{-1} was recorded in case of indoxacarb. It was followed by novaluron and acephate which yielded 262.85 and 258.22 q ha^{-1}, respectively. Minimum fruit yield was recorded from the plots treated with *B. thuringiensis* (206.54 q ha^{-1}) followed by *Ha*NPV (213.24 q ha^{-1}) and quinalphos (220.15 q ha^{-1}). Yield of these three treatments was significantly lower than the all other insecticides and superior to that of control (181.56 q ha^{-1}). The yield obtained from chlorantraniliprole, abamectin and spinosad ranged in between 238.55 to 250.71 q ha^{-1} and ranked in middle order.

The data presented in Table 3 indicated that maximum net profit of Rs. 80970 per hectare was found in indoxacarb (0.01%) followed novaluron (0.01%) and acephate (0.037%) with Rs. 77254 and 71684 net profit per hectare, respectively. The minimum net profit of Rs. 19514 was recorded in spinosad (0.01%) followed by *B. thuringiensis* (0.012%) and *Ha*NPV (250 LE/ha) with Rs. 22664 and 29296 per hectare, respectively. The net profit ranging from Rs. 37306 to 56191 per hectare was computed in quinalphos (0.02%), chlorantraniliprole (0.02%) and abamectin (0.01%).

The highest incremental cost benefit ratio (ICBR) of 30.33 was computed in indoxacarb followed by 29.05 in quinalphos and 19.14 in novaluron. The minimum incremental cost benefit ratio 0.52 was obtained in spinosad followed by abamectin (2.26). The incremental cost benefit ratio ranging from 4.34 to 14.41 was found in acephate, *B. thuringiensis*, chlorantraniliprole and *Ha*NPV.

Table 1: Overall efficacy of insecticides/bio-pesticides on the larval reduction of *H. armigera* infesting tomato after two sprays

S. No.	Treatments	Reduction in larval population (%)					Mean
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS	
1	Acephate 75 SP @ 0.037%	63.41	70.37	63.73	54.60	46.06	59.63
		(52.78)*	(57.03)	(52.98)	(47.64)	(42.73)	(50.63)
2	Quinalphos 25 EC @ 0.02%	54.81	57.35	54.86	41.66	33.63	48.46
		(47.76)	(49.23)	(47.79)	(40.20)	(35.44)	(44.08)
3	*Bacillus thuringiensis* 8L @ 0.012%	48.21	54.88	49.53	39.09	31.65	44.67
		(43.97)	(47.80)	(44.73)	(38.70)	(34.23)	(41.89)
4	Chlorantraniliprole 18.5 SC @ 0.02%	61.20	65.24	60.93	52.82	44.77	56.99
		(51.48)	(53.88)	(51.35)	(46.63)	(41.99)	(49.07)
5	Abamectin 5 SG @ 0.01%	60.40	63.80	59.74	46.89	37.46	53.66
		(51.01)	(53.02)	(50.62)	(43.22)	(37.73)	(47.12)
6	*Ha*NPV @ 250 LE/ha	48.56	57.05	53.40	34.23	30.81	44.81
		(44.17)	(49.05)	(46.95)	(35.80)	(33.70)	(41.93)
7	Indoxacarb 14.5 SC @ 0.01%	68.72	74.13	69.12	57.77	49.11	63.77
		(56.00)	(59.46)	(56.25)	(49.47)	(44.49)	(53.13)
8	Novaluron 10 EC @ 0.01%	66.25	72.13	66.51	56.74	47.60	61.85
		(54.55)	(58.14)	(54.71)	(48.89)	(43.62)	(51.98)
9	Spinosad 2.5 SC @ 0.01%	56.59	61.43	55.97	43.42	34.91	50.46
		(48.78)	(51.61)	(48.43)	(41.22)	(36.21)	(45.25)
10	Control	31.65	32.35	30.65	23.79	18.99	27.49
		(34.22)	(34.65)	(33.62)	(29.19)	(25.83)	(31.50)
	S.Em ±	1.11	0.89	1.11	0.97	1.043	1.02
	CD at 5%	3.29	2.65	3.31	2.88	3.098	3.04

Table 2: Overall efficacy of insecticides/bio-pesticides on fruit damage in tomato after two sprays

S. No.	Treatments	Fruit damage (%)					Mean	Yield ($q\ ha^{-1}$)
		3 DAS**	6 DAS	9 DAS	12 DAS	15 DAS		
1	Acephate 75 SP @ 0.037%	10.31	9.71	10.95	11.55	12.55	11.01	258.22
		(18.73)*	(18.16)	(19.32)	(19.86)	(20.69)	(19.35)	
2	Quinalphos 25 EC @ 0.02%	16.91	16.25	16.81	17.37	17.94	17.06	220.15
		(24.28)	(23.77)	(24.19)	(24.61)	(25.04)	(24.38)	
3	*Bacillus thuringiensis* 8L @ 0.012%	18.52	17.95	19.19	19.55	20.42	19.13	206.54
		(25.49)	(25.06)	(25.98)	(26.24)	(26.86)	(25.93)	
4	Chlorantraniliprole 18.5 SC @ 0.02%	11.97	11.15	12.42	13.10	13.71	12.47	250.71
		(20.24)	(19.50)	(20.60)	(21.19)	(21.70)	(20.65)	
5	Abamectin 5 SG @ 0.01%	13.19	12.40	13.61	14.37	14.79	13.67	241.62
		(21.29)	(20.61)	(21.64)	(22.24)	(22.58)	(21.67)	
6	*Ha*NPV @ 250 LE/ha	17.64	17.17	18.63	19.27	20.10	18.56	213.24
		(24.82)	(24.46)	(25.57)	(26.00)	(26.60)	(25.49)	
7	Indoxacarb 14.5 SC @ 0.01%	8.95	8.00	9.24	9.71	10.47	9.27	265.20
		(17.40)	(16.43)	(17.69)	(18.15)	(18.87)	(17.71)	
8	Novaluron 10 EC @ 0.01%	9.94	9.26	10.34	10.67	11.42	10.33	262.85
		(18.37)	(17.71)	(18.71)	(19.06)	(19.75)	(18.72)	
9	Spinosad 2.5 SC @ 0.01%	13.61	12.68	14.21	14.57	15.54	14.12	238.55
		(21.64)	(20.86)	(22.07)	(22.42)	(23.21)	(22.04)	
10	Control	30.98	33.35	36.51	38.53	41.03	36.08	181.56
		(33.77)	(35.22)	(37.17)	(38.37)	(39.83)	(36.87)	
	S.Em ±	0.68	0.78	0.73	0.67	0.798	0.73	4.23
	CD at 5%	2.01	2.31	2.16	1.99	2.370	2.17	12.58

*Figure in parentheses are angular transformed values, **Days after spray.

Table 3: Comparative economics of insecticides and bio-pesticides against, *H. armigera*

S. No.	Treatments	Mean yield ($q\ ha^{-1}$)	Increased yield over control ($q\ ha^{-1}$)	Cost of increased yield (Rs.)*	Total Expenditure (Rs. ha^{-1})**	Net profit (Rs. ha^{-1})	Incremental cost benefit ratio (ICBR)
1	Acephate 75 SP @ 0.037%	258.22	76.66	76660	4975.40	71684.60	1:14.41
2	Quinalphos 25 EC @ 0.02%	220.15	38.59	38590	1284.00	37306.00	1:29.05
3	*Bacillus thuringiensis* 8L @ 0.01%	206.54	24.98	24980	2316.00	22664.00	1:9.79
4	Chlorantraniliprole 18.5 SC @ 0.02%	250.71	69.15	69150	12959.00	56191.40	1:4.34
5	Abamectin 5 SG @ 0.01%	241.62	60.06	60060	18436.00	41624.00	1:2.26
6	*Ha*NPV @ 250 LE/ha	213.24	31.68	31680	2385.00	29295.00	1:12.28
7	Indoxacarb 14.5 SC @ 0.01%	265.20	83.64	83640	2670.00	80970.00	1:30.33
8	Novaluron 10 EC @ 0.01%	262.85	81.29	81290	4036.00	77254.00	1:19.14
9	Spinosad 2.5 SC @ 0.01%	238.55	56.99	56990	37476.00	19514.00	1:0.52
10	Control	181.56	-	-	-	-	-

* Cost of fruit of tomato at current season was Rs. = 1000 per quintal, **Included cost of insecticides & labour involved in spraying

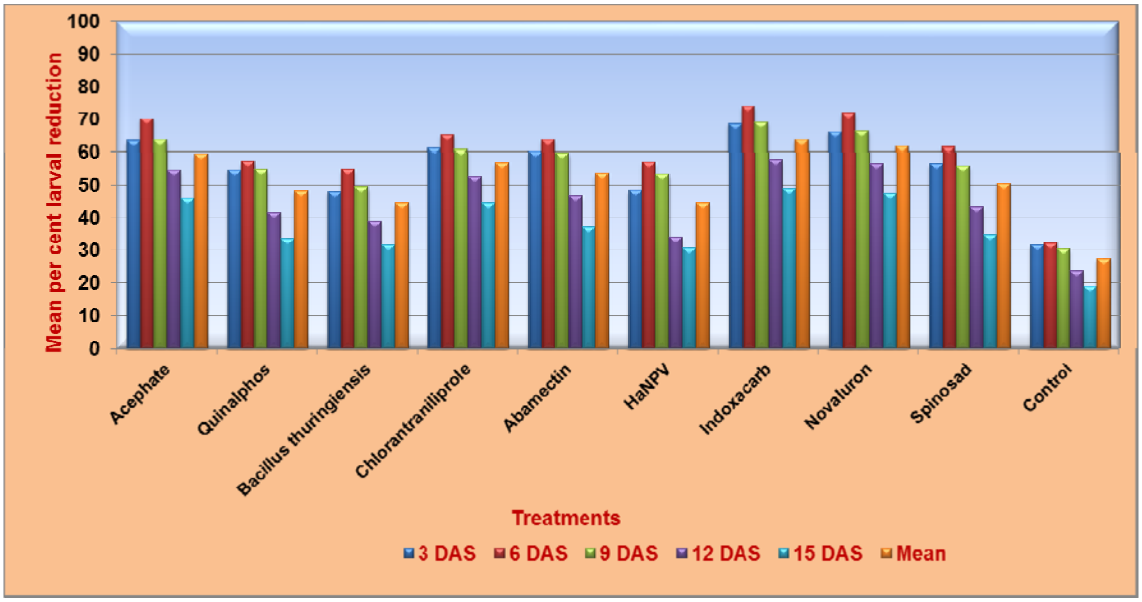

Fig 1: Overall reduction in larval population of *H. armigera* in tomato after two sprays of insecticides/bio-pesticides

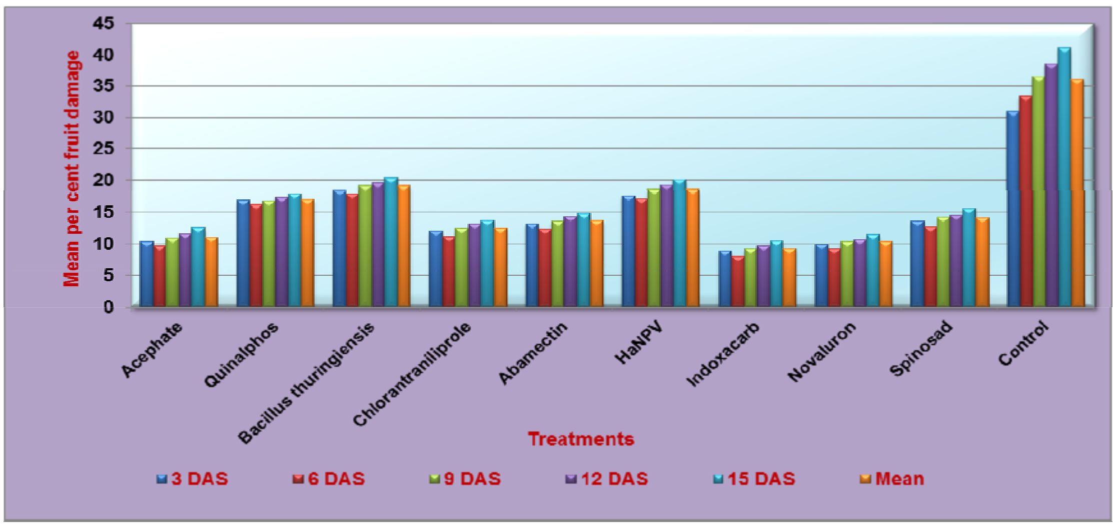

Fig 2: Overall efficacy of insecticides//bio-pesticides on fruit damage in tomato after two sprays

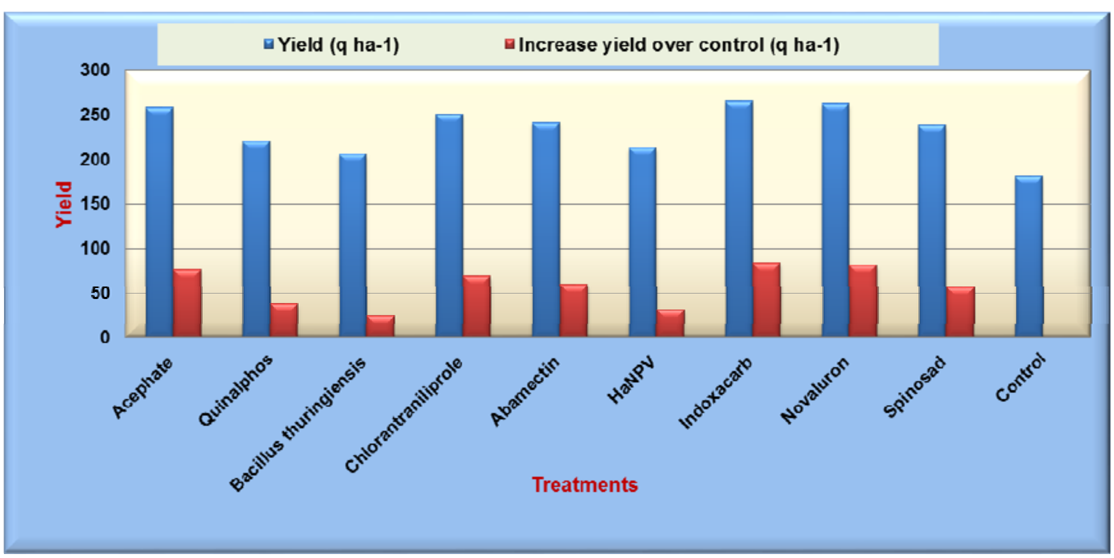

Fig 3: Effect of insecticides on the yield of tomato fruits and increase yield over control

4. Discussion

Investigation on the bio efficacy of nine insecticides against fruit borer in tomato during *rabi* season, 2013-14 were carried out. Meagre work is available on some of insecticides against fruit borer; however, the available literature pertaining to efficacy of insecticides against fruit borer is being compared and discussed.

The result of effectiveness of different insecticidal treatments against tomato fruit borer, *H. armigera* showed that all the treatments were significantly superior over control in terms of mean reduction of tomato fruit borer larvae, mean fruit damage and marketable fruit yield.

The data revealed that indoxacarb (0.01%) was found most effective followed by novaluron (0.01%) and acephate (0.037%) against tomato fruit borer. The present results are in agreement with those of Murray *et al.* (2005) [4], Singh *et al*. (2005) [5], Patil *et al*. (2007) [6], Kuttalam *et al.* (2008) [7] and Dhaka *et al.* (2010) [8] who reported indoxacarb as most effective insecticides against tomato fruit borer. The insecticide novaluron stood second in order of efficacy followed by acephate against fruit borer in present investigation. The spray of novaluron was reported most effective (Saini *et al*. 2013) [9] and second after indoxacarb against fruit borer (Dhaka *et al.* 2010 [8] corroborate the present finding. Singh *et al*. (2005) [5] reported minimum fruit damage with the spray of acephate 75 SP partially confirm the present results.

In the present studies chlorantrailiprole (0.02%) was reported as moderately effective insecticide followed by abamectin (0.01%) and spinosad (0.01%) against fruit borer in tomato. The present results are in partial agreement with that of Gadhiya *et al*. (2014) [10] who reported chlorantrailiprole, abamectin and spinosad as effective insecticides against *H. armigera* on groundnut. Abamectin was reported as significantly superior than quinalphos (Patel *et al.* 2009) [11] and spinosad (Tatagar *et al*. 2009) [12] in reducing *H. armigera* population and fruit damage in tomato corroborates the present results. In the present investigation spinosad was found as moderately effective insecticide and superior than quinalphos get support from the finding of Ghosh *et al.* (2010) [13] who reported spinosad as effective against *H. armigera* on tomato in comparison to quinalphos. Contrary to present results, Siddegowda *et al.* (2006) [14], Patil *et al.* (2007) [6], Kuttalam *et al*. (2008) [7] and Jat and Ameta (2013) [15] had reported spinosad as most effective and at par to the indoxacarb against tomato fruit borer.

In the present investigation the spray of *B. thuringiensis* (0.012%) proved least effective insecticide followed by *Ha*NPV (250 LE/ha) and quinalphos (0.02%). The present findings are not in agreement with those of Mehta *et al.* (2000) [16], Ravi *et al.* (2008) [17], Ram and Singh (2011)[18] and Rahman *et al.* (2014) [19] who reported *B. thuringiensis* and *Ha*NPV effective against tomato fruit borer. Chandrakar *et al.* (1999) [20] and Jat and Ameta (2013) [15] who reported the spray of *B. thuringiensis* as least effective against fruit borer, support the present results. Ravi *et al.* (2008) [17] reported spray of *B. thuringiensis* and *Ha*NPV was equally effective as that of quinalphos, also conform the present results.

The highest marketable fruit yield 265.20 q ha^{-1} was recorded in case of indoxacarb followed by novaluron and acephate which yielded 262.85 and 258.22 q ha^{-1}, respectively. The yield ranging from 18.31 q ha^{-1} to 602.78 q ha^{-1} with the indoxacarb (Patil *et al.* 2007, Dhaka *et al.* 2010 and Singh *et al*. 2005) [6, 8, 5] have been reported earlier which support the present findings.

Minimum fruit yield was recorded from the plots treated with *B. thuringiensis* (206.54 q ha^{-1}) followed by *Ha*NPV (213.24 q ha^{-1}) and quinalphos (220.15 q ha^{-1}). Dhaka *et al.* (2010) [8] and Ram and Singh (2011) [18] reported lower yield with the treatment of *B. thuringiensis* and *Ha*NPV as compared to chemical insecticides. However, contrary to the present findings, Chandrakar *et al.* (1999) [20] and Rahman *et al.* (2014) [19] reported highest fruit yield with the treatment of *B. thuringiensis* and *Ha*NPV.

Yield obtained from chlorantraniliprole, abamectin and spinosad ranged in between 238.55 to 250.71 q ha^{-1} and ranked in middle order. The present findings does not corroborate with that of Ghosal *et al.* (2012) [21] who obtained 34.74 q ha^{-1} yield in chlorantraniliprole which is highest in comparison to spinosad and indoxacarb. However, Jat and Ameta (2013) [15] reported that yield obtained from spinosad is in middle order confirm the present results. Yield data of novaluron, abamectin and quinalphos is not available, therefore, it could not be compared and the data revealed that during the present investigation, the maximum net profit of Rs. 80970 per hectare was recorded from indoxacarb (0.01%) followed by novaluron (0.01%) and acephate (0.037%) with Rs. 77254 and 71684 net profit per hectare, respectively. The minimum net profit of Rs. 19514 was recorded from spinosad (0.01%) followed by *B. thuringiensis* (0.012%) and *Ha*NPV with Rs. 22664 and 29296 net profit per hectare, respectively. The net profit ranging from Rs. 37306 to 56191 per hectare was computed in quinalphos (0.02%), chlorantraniliprole (0.02%) and abamectin (0.01%).

The net profit of Rs. 75645 was found in acephate which was at par to the indoxacarb by Singh *et al.* (2005) [5], corroborate the present findings. However, the net profit of Rs. 14139 by Dhaka *et al.* (2010) [8] and Rs. 21288 by Kumar and Devi (2014) [22] are not in agreement with the present results. The net profit of Rs. 20070.50 and Rs. 21026 reported by Moorthy *et al.* (2011) [23] and Kumar and Devi (2014) [22], respectively from the treatment of spinosad are in agreement with the results of present studies. Sharma and Bhardwaj (2008) [24] reported net profit in the range of Rs. 16484 to 32937 from *Ha*NPV and *B. thuringiensis* also corroborate the present findings.

Roopa and Kumar (2014) [25] reported net profit of Rs. 740661 from spinosad, Rs. 651475 from abamectin, Rs. 586387 from novaluron, Rs. 574461 from indoxacarb, Rs. 551491 from chlorantraniliprole and Rs. 329863 from quinalphos does not support the present results.

The highest incremental cost benefit ratio of 30.33 was computed in indoxacarb followed by 29.05 in quinalphos and 19.14 in novaluron. The minimum incremental cost benefit ratio 0.52 was obtained in spinosad followed by abamectin (2.26). The incremental cost benefit ratio ranging from 4.34 to 14.41 was found in acephate, *B. thuringiensis*, chlorantraniliprole and *Ha*NPV. Contrary to the present finding, Sreekanth *et al.* (2014) [26] 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 (2013) [15] reported the highest incremental cost benefit ratio of 1:2.075 in spinosad also does not support the present results. Rahman *et al.* (2014) [19] obtained the highest incremental cost benefit ratio (5.30) from alternate spray of *Ha*NPV and *B. thuringiensis* followed by alone spray of *Ha*NPV (4.46) and *B. thuringiensis* (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.

5. Conclusion

The experiment on bio-efficacy of different insecticidal treatments revealed that indoxacarb was found most effective against fruit borer followed by novaluron and acephate and resulted higher yield, while *B. thuringiensis* proved least effective followed by HaNPV and quinalphos. The treatments chlorantraniliprole, abamectin and spinosad ranked in middle order of their efficacy.

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