International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 2139-2143

Received: 05-09-2018
Accepted: 10-10-2018

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Evaluation of different biopesticides against mango leafhoppers

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Abstract
Mango leafhoppers are an important insect pest in mango ecosystem. Attempt was made to evaluate different biopesticides against mango leafhoppers. Among eight treatments imposed for the management of mango leafhoppers the treatment with Azadirachtin 5 EC (12.71 leafhopper / inflorescence) recorded significantly lower number of leafhoppers followed by Azadirachtin 1EC (14.41 leafhopper / inflorescence) and Lastraw 30 per cent (15.71 leafhopper / inflorescence). However, the standard check imidacloprid 17.8 SL @ 0.25 ml/lit recorded significantly lower number of leafhoppers (3.93 leafhopper / inflorescence). Highest yield of 65.12 q/ha was recorded in the treatment with Imidacloprid 17.8 SL. The economic analysis of different bio pesticides, imidacloprid gave highest returns with C: B ratio of 1: 3.13. Azadirachtin 5 EC stood second in giving returns with a C: B ratio of 1: 2.38 followed by Azadirachtin 1 EC (1: 2.30).

Keywords: mango leafhopper, biopesticides

Introduction
Mango is the most ancient among the tropical fruits and is believed to have originated in Indo-Burma region. *Mangifera indica* L. is the national fruit of India and since long it is the choicest fruit in India. This fruit has been in cultivation in India sub-continent for well over 4000 years and has been the favourite of the kings and commoners because of its nutritive value, taste, attractive fragrance and health promoting qualities. Among the pests that occur on mango, leafhoppers are economically important [1]. Mango hopper is a serious pest, which may cause up to 50% crop loss in cases of severe infestation. This pest is expected to emerge from the last week of February to first week of March. This is the most important pest recorded during the flowering seasons throughout Bihar. Among many species of hoppers reported, *Idioscopus clypealis* L., *I. niveosparsus* L. and *Amritodus atkinsoni* L. are of major importance, persistent on panicles and leaves, respectively. Mango hoppers were found colonized during both vegetative and reproductive phase of the crop. Peak incidence was noticed during full bloom stage after which the insects migrated to cracks and crevices of the trunk. Pesticidal residues in fresh mangoes are affecting export there by leading to financial loss. To combat these problems, there is a need to develop the management techniques which are eco-friendly and safer to natural enemies. The organic pest management programs can significantly benefit mango growers, considering the market potential for the organic produce. Further, these programs are also eco-friendly [2]. Keeping these aspects in view, the present study on evaluation of different bio pesticides against mango leafhoppers was carried out.

Material and Methods
The present study entitled, "Evaluation of different bio pesticides against mango leafhoppers" was carried out with a view to manage the mango leafhoppers with the help of some conventional biopesticides. A field experiment was conducted during 2016-17 in a farmer's field at Doddabbigere, during flowering season on Alphonso variety of 10 years old trees with 10x10 meters spacing. The experiment consists of 8 treatments (including standard and untreated check) and each treatment was replicated thrice. Each tree was considered as one replication.

Table 1: Treatment details of different bio pesticides against mango leafhoppers

Treatments	Details	Dosage
T_1	*Beauveria bassiana* (1 x 10^8 cfu / g)	2g /lit
T_2	*Verticilium leccanii* (1 x 10^8 cfu / g)	2g /lit
T_3	*Metarrhizium anisopliae* (1 x 10^8 cfu/ g)	2g /lit
T_4	Azadirachtin 1 EC	3ml /lit
T_5	Lastraw 30 per cent	5ml /lit
T_6	Azadirachtin 5 EC	2ml /lit
T_7	Imidacloprid 17.8 SL (standard check)	0.25 ml/lit
T_8	Un treated check	-

Spray fluid

The required quantity of spray solution was prepared at the time of application. The quantity of spray fluid required per tree was approximately eight liters.

Spray schedule

The spraying was taken up two times. First spray was taken at flower initiation stage and the second spray at 21 days after first spray. Pre-treatment count of leafhoppers was made one day before application on inflorescence (Two inflorescences in each direction covering all the directions including the tree trunk) and expressed as number of nymphs / adults per inflorescence. Post treatment counts were taken at 3, 5, 7 and 15 days after the spray. After harvesting, the yield of each treated tree was taken.

Economic analysis

Based on the yield data, the gross returns and net returns were calculated for each treatment. The benefit cost ratio (BC) was determined by calculating the yield, cost of plant protection and total cost of production in each treatment. The gross returns were worked out by taking the selling price of mango as Rs.2000/q. The net returns of different treatments were worked out by deducting total cost of production from gross returns. Finally the B: C ratio was worked out by dividing gross returns and total cost of production in each treatment.

Cost of plant protection

Based on prevailing market price of insecticides, cost of labors and cost of inputs, the cost of plant protection was worked out.

Net return

Net return (Rs./ha) was calculated by subtracting the cost of plant protection (Rs./ha) from gross return**.**

Benefit cost ratio

Benefit cost ratio was calculated by using the formula:

$$\text{BC ratio} = \frac{\text{Gross returns (Rs /ha)}}{\text{Total cost of production (Rs /ha)}}$$

Results and Discussion

First spray

Results of the field trial on effectiveness of bio pesticides during first spray are presented in the table 2. There were no significant differences in population of mango leafhoppers a day before treatment imposition and the leafhoppers population ranged from 22.33 to 25.67 leafhoppers /inflorescence.

At three days after first spray, from the results it was observed that among the entomopathogens *V. leccanii* recorded significantly lower leafhoppers (17.75 leafhoppers) and it was on par with *M. anisoplae* (18.58 leafhoppers) and *B. bassiana* (19.33 leafhoppers). Azadirachtin 1 EC (14.25 leafhoppers) and Lastraw 30 per cent (16.50 leafhoppers) were statistically on par with each other. The other treatment Azadirachtin 5 EC recorded significantly lower number of leafhoppers (12.83 leafhoppers) as compared to the above mentioned treatments. The standard check Imidacloprid 17.8 SL recorded significantly lower leafhoppers (1.50 leafhoppers) while significantly higher numbers of leafhoppers were noticed in untreated check (23.98 leafhoppers).

At five days after first spray, significantly lower numbers of leafhoppers were observed in Azadirachtin 5 EC (12.00 leafhoppers). The next best treatment was Azadirachtin 1 EC found statistically on par with Lastraw 30 per cent and *V. leccanii*. Among the entomopathogens, significantly lower number of leafhoppers was recorded in *V. leccanii* (16.42 leafhoppers) and was found superior over *M. anisoplae* and *B. bassiana*. The standard check imidacloprid 17.8 SL recorded significantly lower leafhoppers (1.33 leafhoppers) as against significantly higher numbers of leafhoppers in untreated check (29.48 leafhoppers).

At seven days after first spray, lower numbers of leafhoppers were observed in Azadirachtin 5 EC (12.25 leafhoppers) followed by Azadirachtin 1 EC which recorded lower counts of leafhoppers (13.92) and was statistically on par with lastraw 30 per cent (15.92 leafhoppers) and *V. leccanii* (16.92 leafhoppers). The other entomopathogens, *B. bassiana* and *M. anisoplae* did not differ significantly in suppression of leafhoppers. Imidacloprid 17.8 SL recorded significantly lower leafhoppers (1.83 leafhoppers). Untreated check recorded significantly higher numbers of leafhoppers (38.38 leafhoppers).

At fifteen days after first spray Imidacloprid 17.8 SL @ 0.25 ml/lit recorded significantly lower number of leafhoppers (11.67 leafhoppers). Azadirachtin 5 EC recorded lower number of leafhoppers (18.42 leafhoppers) and was found on par with remaining treatments (Azadirachtin 1 EC, Lastraw 30 per cent and entomopathogens). The untreated check recorded significantly higher leafhopper population (31.87 leafhoppers).

Data on post treatment mean revealed that Imidacloprid 17.8 SL @ 0.25 ml/lit recorded significantly lower number of leafhoppers (4.08 leafhoppers) followed by Azadirachtin 5 EC (13.88 leafhoppers). Azadirachtin 1 EC, Lastraw 30 per cent and *V. leccanii* were found on par with each other. Entomopathogens, *B. bassiana* and *M. anisopliae* were on par with each other. Significantly higher leafhoppers were noticed in untreated check (30.93 leafhoppers).

Computed data of per cent reduction over control indicated that highest per cent leafhopper suppression was registered with Imidacloprid 17.8 SL @ 0.25 ml/lit (86.81 %) followed by Azadirachtin 5 EC (55.12 %), Azadirachtin 1 EC (50.63 %) and Lastraw 30 per cent (45.65 %). The per cent reduction in entomopathogens treatments varied from 38.15 % to 42.74 %.

Table 2: Effect of different bio pesticides against mango leafhoppers (First spray) during 2016-17

Sl No	Treatments	Dosage(ml/ g/lit)	Mean number of nymphs or adults / panicle					Post Treatment mean	Per cent reduction over control
			1 DBFS	3 DAFS	5 DAFS	7 DAFS	15 DAFS		
1	*Beauveria bassiana* (1 x 108 cfu / g)	2g /lit	23.50 (4.89)	19.33 (4.45)^{ab}	18.58 (4.37)^{b}	19.00 (4.42)^{b}	19.62 (4.48)^{b}	19.13 (4.43)^{b}	38.15
2	*Verticilium leccanii* (1 x 108 cfu / g)	2g /lit	24.67 (4.99)	17.75 (4.27)^{abc}	16.42 (4.11)^{bc}	16.92 (4.17)^{bc}	19.75 (4.50)^{b}	17.71 (4.26)^{bc}	42.74
3	*Metarrhizium anisopliae* (1 x 108 cfu / g)	2g /lit	22.33 (4.75)	18.58 (4.36)^{ab}	17.83 (4.28)^{b}	18.25 (4.32)^{b}	19.00 (4.41)^{b}	18.42 (4.35)^{b}	40.45
4	Azadirachtin 1 EC	3ml /lit	23.08 (4.84)	14.25 (3.83)^{bc}	13.58 (3.74)^{bc}	13.92 (3.78)^{bc}	19.33 (4.45)^{b}	15.27 (3.96)^{bc}	50.63
5	Lastraw 30 per cent	5ml /lit	24.00 (4.94)	16.50 (4.08)^{bc}	15.67 (3.98)^{bc}	15.92 (4.02)^{bc}	19.17 (4.43)^{b}	16.81 (4.16)^{bc}	45.65
6	Azadirachtin 5 EC	2ml /lit	22.75 (4.80)	12.83 (3.63)^{c}	12.00 (3.52)^{c}	12.25 (3.56)^{c}	18.42 (4.33)^{b}	13.88 (3.78)^{c}	55.12
7	Imidacloprid 17.8 SL (standard check)	0.25 ml/lit	25.67 (5.11)	1.50 (1.41)^{d}	1.33 (1.35)^{d}	1.83 (1.52)^{d}	11.67 (3.48)^{c}	4.08 (1.95)^{d}	86.81
8	Control	-	23.00 (4.82)	23.98 (4.93)^{a}	29.48 (5.47)^{a}	38.38 (6.24)^{a}	31.87 (5.67)^{a}	30.93 (5.59)^{a}	0.00
	S.E.m±	-	0.295	0.236	0.223	0.211	0.177	0.191	-
	CD(0.05)	-	0.894	0.717	0.675	0.641	0.538	0.560	-
	CV (%)	-	10.435	10.580	10.018	9.170	6.869	9.392	-

DBFS: Day before first spray; DAFS: Days after first spray; Values in the parentheses are$\sqrt{x+1}$ transformed value; Means followed by same letters do not differ significantly by DMRT (P=0.05)

Second spray

Second spray was taken 21 days after first spray. Results of the field trial on effectiveness of bio pesticides during second spray are presented in the table 3.

Similar trend was observed in the second spray. A day prior to second spray significantly lower population was noticed in the treatment with Imidacloprid 17.8 SL @ 0.25 ml/lit (11.83 leafhoppers). Among the other treatments there were no significant differences in population of mango leafhoppers except untreated check where in it has recorded significantly higher numbers of leafhoppers (30.62 leafhoppers).

After three days, significantly lower leafhopper population was recorded with Imidacloprid 17.8 SL @ 0.25 ml/lit (1.48 leafhoppers). Azadirachtin 5 EC recorded significantly lower number of leafhopper population (10.21 leafhoppers) and it statistically on par with Azadirachtin 1 EC followed by Lastraw 30 per cent (13.64) and *V. leccanii* (15.56) and was found superior over *B. bassiana* and *M. anisopliae*. However, the higher number leafhoppers were noticed in untreated check (26.93 leafhoppers).

Five days after second spray, the population of leafhoppers varied between 1. 31 to 25.92 per panicle. Significantly lowest leafhoppers were noticed in treatment with Imidacloprid 17.8 SL @ 0.25 ml/lit (1.31 leafhoppers). The next best treatment is Azadirachtin 5 EC which recorded significantly lower number of leafhopper population (9.78 leafhoppers) and it statistically on par with Azadirachtin 1 EC (11.70 leafhoppers) followed by Lastraw 30 per cent.

Among the entomopathogens, *V. leccanii* recorded lower number of leafhoppers (14.84) and it is on par with Lastraw 30 per cent. *M. anisopliae* recorded higher number of leafhoppers (16.00) and it is on par with *B. bassiana*. The untreated check recorded significantly higher leafhopper population (30.25 leafhoppers).

Seven days after second spray, similar results were seen. Significantly lower leafhopper population was recorded with Imidacloprid 17.8 SL @ 0.25 ml/lit (1.83 leafhoppers). The next best treatment is Azadirachtin 5 EC which recorded significantly lower number of leafhopper population (10.62 leafhoppers) and it statistically on par with Azadirachtin 1 EC. Lastraw 30 per cent also recorded lower number of leafhoppers (14.21) and it is on par with *V. leccanii*. *M. anisopliae* recorded higher number of leafhoppers (16.69) and it is on par with *B. bassiana*. The untreated check recorded significantly higher leafhopper population (30.46 leafhoppers).

Significantly lower leafhopper population was recorded with Imidacloprid 17.8 SL @ 0.25 ml/lit (10.49 leafhoppers) at fifteen days after second spray. Azadirachtin 5 EC recorded significantly lower number of leafhopper population (15.52 leafhoppers) and it statistically on par with all other treatments. The untreated check recorded significantly higher leafhopper population (30.36 leafhoppers).

Post treatment mean of second spray revealed that the treatment with Imidacloprid 17.8 SL @ 0.25 ml/lit registered significantly lower numbers of leafhoppers (3.78 leafhoppers). Azadirachtin 5 EC recorded significantly lower number of leafhopper population (11.54 leafhoppers) and it statistically on par with Azadirachtin 1 EC. Lastraw 30 per cent also recorded lower number of leafhoppers (14.61) and it is on par with *V. leccanii* and *M. anisopliae* but *B. bassiana* recorded higher number of leafhoppers (17.40). The untreated check recorded significantly higher leafhopper population (30.33 leafhoppers).

Computed data of per cent reduction over control indicated that the highest per cent reduction of leafhopper population over control was registered with Imidacloprid 17.8 SL @ 0.25 ml/lit (87.57%) closely followed by Azadirachtin 5 EC (61.98%), Azadirachtin 1 EC (55.32%) and Lastraw 30 per cent (51.86%). The per cent reduction of entomopathogens varied from 42.66 to 47.84.

Table 3: Effect of different bio pesticides against mango leafhoppers (Second spray) during 2016-17

Sl. No.	Treatments	Dosage (ml/ g/lit)	Mean number of nymphs or adults / panicle					Post Treatment mean	Per cent reduction over control
			1 DBSS	3 DASS	5 DASS	7 DASS	15 DASS		
1	*Beauveria bassiana* (1 x 108 cfu / g)	2g /lit	19.76 (4.50)^{b}	16.96 (4.17)^{b}	16.35 (4.09)^{b}	17.10 (4.19)^{b}	19.17 (4.43)^{a}	17.40 (4.23)^{b}	29.00
2	*Verticilium lecanii* (1 x 108 cfu / g)	2g /lit	19.30 (4.45)^{b}	15.56 (4.00)^{bc}	14.84 (3.91)^{b}	15.53 (4.00)^{b}	17.36 (4.23)^{ab}	15.82 (4.04)^{b}	35.45
3	*Metarrhizium anisopliae* (1 x 108 cfu / g)	2g /lit	18.93 (4.40)^{b}	16.53 (4.12)^{bc}	16.00 (4.06)^{b}	16.69 (4.14)^{b}	17.02 (4.18)^{ab}	16.56 (4.13)^{b}	32.43
4	Azadirachtin 1 EC	3ml /lit	19.45 (4.46)^{b}	12.37 (3.59)^{de}	11.70 (3.49)^{cd}	12.37 (3.57)^{cd}	17.78 (4.27)^{ab}	13.56 (3.74)^{bc}	44.68
5	Lastraw 30 per cent	5ml /lit	19.86 (4.51)^{b}	13.64 (3.76)^{cd}	13.27 (3.71)^{bc}	14.21 (3.83)^{bc}	17.30 (4.21)^{ab}	14.61 (3.88)^{bc}	40.39
6	Azadirachtin 5 EC	2ml /lit	18.57 (4.35)^{b}	10.21 (3.27)^{e}	9.78 (3.20)^{d}	10.62 (3.33)^{d}	15.52 (3.99)^{b}	11.54 (3.45)^{c}	52.92
7	Imidacloprid 17.8 SL (standard check)	0.25 ml/lit	11.83 (3.51)^{c}	1.48 (1.40)^{f}	1.31 (1.35)^{e}	1.83 (1.52)^{e}	10.49 (3.31)^{c}	3.78 (1.90)^{d}	84.58
8	Control	-	30.62 (5.56)^{a}	26.93 (5.24)^{a}	25.92 (5.14)^{a}	24.46 (4.99)^{a}	20.73 (4.61)^{a}	24.51 (5.00)^{a}	0.00
	S.E.m±	-	0.193	0.127	0.133	0.126	0.145	0.175	-
	CD(0.05)	-	0.587	0.386	0.403	0.382	0.439	0.514	-
	CV (%)	-	7.497	5.969	6.364	5.898	6.032	9.212	-

DBSS: Day before second spray; DASS: Days after second spray; Values in the parentheses are $\sqrt{x+1}$ transformed value; Means followed by same letters do not differ significantly by DMRT (P=0.05)

Mean number of leafhoppers population in different treatments (both first and Second spray)

Post treatment mean of both sprays revealed that significantly lower number of leafhopper population was recorded in Imidacloprid 17.8 SL @ 0.25 ml/lit (3.93 leafhoppers). The next best treatment is Azadirachtin 5 EC which recorded lower number of leafhoppers (12.71 leafhoppers) and it statistically on par with Azadirachtin 1 EC and Lastraw 30 per cent. Among the entomopathogens *V. leccanii* recorded lower number of leafhoppers (16.77) followed by *M. anisopliae*. The other entomopathogen *B. bassiana* recorded higher number of leafhoppers (18.26 leafhoppers). However, the higher number leafhoppers were noticed in untreated check (27.72 leafhoppers) (Table 4).

Table 4: Effect of different bio pesticides against mango leafhoppers (POOLED) during 2016-17

Sl No.	Treatments	Dosage(ml/ g/lit)	Mean number of nymphs or adults / panicle					Post Treatment mean	Per cent reduction over control	Yield (q/ha)
			1 DBS	3 DAS	5 DAS	7 DAS	15 DAS			
1	*Beauveria bassiana* (1 x 108 cfu / g)	2g /lit	21.63 (4.70)	18.15 (4.32)^{b}	17.47 (4.24)^{b}	18.05 (4.31)^{b}	19.39 (4.46)^{b}	18.26 (4.33)^{b}	34.13	40.00^{e}
2	*Verticilium leccanii* (1 x 108 cfu / g)	2g /lit	21.99 (4.73)	16.66 (4.14)^{b}	15.63 (4.02)^{bc}	16.22 (4.09)^{bc}	18.56 (4.36)^{b}	16.77 (4.15)^{b}	39.50	43.15^{de}
3	*Metarrhizium anisopliae* (1 x 108 cfu / g)	2g /lit	20.63 (4.59)	17.56 (4.25)^{b}	16.92 (4.17)^{bc}	17.47 (4.23)^{b}	18.01 (4.30)^{b}	17.49 (4.24)^{b}	36.90	41.75^{e}
4	Azadirachtin 1 EC	3ml /lit	21.27 (4.66)	13.31 (3.71)^{cd}	12.64 (3.62)^{de}	13.15 (3.68)^{cd}	18.56 (4.36)^{b}	14.41 (3.85)^{bc}	48.01	52.12^{c}
5	Lastraw 30 per cent	5ml /lit	21.93 (4.73)	15.07 (3.93)^{bc}	14.47 (3.86)^{cd}	15.07 (3.94)^{bc}	18.23 (4.33)^{b}	15.71 (4.02)^{bc}	43.33	49.35^{cd}
6	Azadirachtin 5 EC	2ml /lit	20.66 (4.60)	11.52 (3.46)^{d}	10.89 (3.37)^{e}	11.44 (3.45)^{d}	16.97 (4.18)^{b}	12.71 (3.62)^{c}	54.15	58.55^{b}
7	Imidacloprid 17.8 SL (standard check)	0.25 ml/lit	18.75 (4.38)	1.49 (1.41)^{e}	1.32 (1.35)^{f}	1.83 (1.52)^{e}	11.08 (3.40)^{c}	3.93 (1.92)^{d}	85.82	65.12^{a}
8	Control	-	26.81 (5.20)	25.45 (5.09)^{a}	27.70 (5.31)^{a}	31.42 (5.65)^{a}	26.31 (5.17)^{a}	27.72 (5.31)^{a}	0.00	31.55^{f}
	S.E.m±	-	0.184	0.134	0.124	0.138	0.119	0.174	-	2.063
	CD(0.05)	-	0.559	0.408	0.377	0.420	0.360	0.518	-	6.258

DBS: Day before spray; **DAS:** Days after spray; values in the parentheses are $\sqrt{x+1}$ transformed value; Means followed by same letters do not differ significantly by DMRT (P=0.05)

Table 5: Cost economics of bio pesticides against Mango leafhoppers

Sl. No	Treatments	Dosage (ml or g/lit)	Fruit Yield (q/ha)	Yield increment over control (%)	Cost of Production (Rs/ha)	Cost of protection (Rs/ha)	Total cost of Production (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	C:B ratio
1	*Beauveria bassiana* (1 x 108 cfu / g)	2g /lit	40.00^{e}	21.13	40000	2000	42000	80000	34000	1: 1.90
2	*Verticilium leccanii* (1 x 108 cfu / g)	2g /lit	43.15^{de}	26.88	40000	2000	42000	86300	44300	1: 2.05
3	*Metarrhizium anisopliae* (1 x 108 cfu / g)	2g /lit	41.75^{e}	26.20	40000	2000	42000	83500	41500	1: 1.99
4	Azadirachtin 1 EC	3ml /lit	52.12^{c}	39.50	40000	5400	45400	104240	58840	1: 2.30
5	Lastraw 30 per cent	5ml /lit	49.35^{cd}	36.07	40000	4300	44300	98700	54400	1: 2.23

6	Azadirachtin 5 EC	2ml /lit	58.55[b]	46.11	40000	9160	49160	117100	67940	1: 2.38
7	Imidacloprid 17.8 SL (standard check)	0.25 ml/lit	65.12[a]	51.55	40000	1600	41600	130240	88640	1: 3.13
8	Control	-	31.55[f]	-	40000	0	40000	63100	23100	1: 1.58

Quantity of spray fluid used: 8 lit/tree or 984 litres/ha. (no. of trees / ha = 123, 9x9 m spacing)
Price of marketable fruits (Alphonso-mango): Rs. 20.00/Kg (Rs. 2000/q)
No. of labours employed per spray: 2, Labour charge: Rs. 300 per head per day
Cost of the insecticides : Imidacloprid 17.8 SL- Rs. 163 /100ml, *B. bassiana, V. leccanii M. anisopliae*- Rs.200 /500g each Azadirachtin 50000 ppm - Rs. 995/ 250ml, Azadirachtin 10000 ppm- Rs. 1402 /lit, Lastraw 30 per cent- Rs. 310/500 ml

Mean per cent reduction of leafhoppers population over control in both the sprays

Computed data of mean percent reduction of leafhoppers population over control in both the sprays indicated that the highest per cent reduction was registered with Imidacloprid 17.8 SL @ 0.25 ml/lit (85.82 %) followed by Azadirachtin 5 EC (54.15 %), Azadirachtin 1 EC (48.01 %) and Lastraw 30 per cent (43.33 %). The per cent reduction of entomopathogens varied from 34.13 to 39.50 %.

These results are in line with [3] who reported that econeem (1%) was effective against mango leafhoppers. The effectiveness of Azadirachtin was also reported by [4] who evaluated four neem derivatives, Azadirachtin (0.25%) against leafhopper *I. nitidulus.* [5] reported that among two neem formulations, oil based formulation was more effective against *A. atkinsoni* and *I. nitidulus* than kernel based formulation. [6] Found margosa @ 5 ml per liter resulted in a mortality of 72 per cent.

Effectiveness of *L. lecanii* was reported by [7] who recorded maximum numbers of dead leafhoppers (35.3± 9.94 leafhoppers/20 shoots) due to fungal (*L. lecanii*) infection in that *I. nitidulus* constituted over 90 per cent of the total dead leafhoppers. Similarly, [8] also noticed the natural incidence of *Verticillium lecanii* (*Lecanicillium muscarium* (Peach.)) on leafhoppers.

Highest yield of 65.12 q/ha was recorded in the treatment with Imidacloprid 17.8 SL. This was obviously due to its effective suppression of leafhoppers. Azadirachtin 5 EC (2ml/l) was the next best treatment by recording higher fruit yield (58.55 q/ha) followed by Azadirachtin 1 EC (52.12 q/ha) and Lastraw 30 per cent (49.35 q/ha). Among the entomopathogens *V. leccanii* recorded higher yield (43.15 q/ha) followed by *M. anisopliae* (41.75 q/ha) and *B. bassiana* (40.00 q/ha). However, in the economic analysis of different bio pesticides, though the treatment with imidacloprid 17.8 SL gave highest returns with C: B ratio of 1: 3.13, Azadirachtin 5 EC stood second in giving returns with an C: B ratio of 1: 2.38 followed by Azadirachtin 1 EC (1: 2.30).

Based on the C: B ratio, the different bio pesticides were ranked as follows, imidacloprid 17.8 SL > Azadirachtin 5 EC > Azadirachtin EC > Lastraw 30 per cent > *V. leccanii* > *M. anisopliae* > *B. bassiana.*

Yield attributes and yield

Yield is the ultimate reflection of efficiency of any pest management strategy. In the present investigation trees sprayed with Imidacloprid 17.8 SL @ 0.25 ml/lit produced significantly highest yield of 65.12 q/ha. Azadirachtin 5 EC (2ml/l) was the next best treatment by recording higher fruit yield (58.55 q/ha) (Table 5) followed by treatment with Azadirachtin 1 EC (52.12 q/ha) and Lastraw 30 per cent (49.35 q/ha). Among the entomopathogens *V. leccanii* recorded higher yield (43.15 q/ha) followed by *M. anisopliae* (41.75 q/ha) and *B. bassiana* (40.00 q/ha) and respectively.

Economic analysis

Among the seven different treatments, treatment with Imidacloprid 17.8 SL (0.25ml/l) resulted in highest yield of 65.12 q/ha with a net returns of Rs. 88640 and a cost benefit ratio (CB) of 1: 3.13 (Table 5). The second best treatment was Azadirachtin 5 EC which registered a yield of 58.55 q/ha and CB ratio of 1: 2.38 followed by Azadirachtin 1 EC (1: 2.30) and Lastraw 30 per cent (1: 2.23). Among the entomopathogens *V. leccanii* recorded the higher CB ratio of 1: 2.05 followed by *M. anisopliae* (1: 1.99) and *B. bassiana* (1: 1.90) respectively.

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