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Bio-efficacy of different biopesticides against hopper, *Amritodus atkinsoni* Lethierry infesting mango

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Abstract
In order to evaluate the bio-efficacy of various biopesticides against hopper, *Amritodus atkinsoni* infesting mango, a field experiment was conducted at Anand Agricultural University, Anand during 2018. Among the eight biopesticides evaluated, neem seed kernel extract (NSKE) 5 per cent was found the most effective followed by *Lecanicillium lecanii* 1.15% WP, neem oil 1 per cent and neem leaf extract (NLE) 10 per cent in reducing the incidence of *A. atkinsoni*. Maximum (118.77 q/ha) mango fruit yield was recorded from the trees treated with NSKE which was at par with *L. lecanii* 1.15% WP, neem oil 1 per cent and neem leaf extract (NLE) 10 per cent with yield of 116.27, 110.79 and 108.03 q/ha, respectively. The highest (1:13.16) return was obtained with the treatment of NSKE followed by *L. lecanii* 1.15% WP (1:12.56), neem oil (1:11.23) and NLE (1:10.56).

Keywords: Mango, mango hoppers, Langra, *Amritodus atkinsoni*

Introduction
Mango (*Mangifera indica* Linnaeus) is the national fruit of India as it has originated in India and is known as "King of fruits" due to its excellent taste, wide adaptability, exemplary nutritive value, exotic flavour, richness in variety, attractive colour, and popularity among other fruits. Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Telangana, Tamil nadu, Maharashtra and Gujarat are major mango producing states of the country. Gujarat ranks 8th in area occupying 1,53,180 ha area, 5th in production with 1.44 million metric tonnes of production (Anon., 2018) [1]. The crop is attacked by about 492 species of insects, 17 species of mites and 26 species of nematodes at the world level. Of these, 188 species of insects have been reported from India (Tandon and Verghese, 1985) [6]. Among all, *Idioscopus clypealis*, *I. niveosparsus*, *I. nagpurensis* and *Amritodus atkinsoni* are important species of hoppers infesting mango (Pena *et al.*, 1998) [4]. According to Rahman and Kuldeep (2007) [5] mango hoppers cause 20-100 per cent yield loss by giving rise to growth of sooty mould that reduces photosynthetic efficiency of leaves and market quality of fruits. Physical injury is also caused to leaves, panicles and shoots due to egg laying in the tissues. Interest in biopesticides, dates back to over hundred years. Biopesticides have an essential role in IPM because it can be used along with other strategies for sustainable insect-pest management. They cause regularly a considerable mortality of varied insect pests in many parts of the world and thus, constitute an efficient and extremely important natural control factor (Steinhaus, 1949) [7]. The safety of biopesticides towards humans, the environment and non-target organisms is an important criteria and offers a safer alternative for application in IPM over continuously evolving chemical insecticides.

Materials and Methods
For evaluation of various biopesticides against hopper, *A. atkinsoni* infesting mango an experiment was conducted under field conditions on farm of B. A. College of Agriculture, Anand Agricultural University, Anand during 2018. The experiment was laid out in Completely Randomized Design with nine treatments *viz.*, neem seed kernel extract (NSKE) 5 per cent, *L. lecanii* 1.15% WP (1 x 10^9 cfu/g) 0.4 per cent, neem oil 0.5 per cent, neem leaf extract (NLE) 10 per cent, garlic bulb extract (GBE) 5 per cent, *Beauveria bassiana* 5% WP (1 x 10^9 cfu/g) 0.4 per cent, *Metarhizium anisopliae* 1.15% WP (1 x 10^9 cfu/g) 0.4 per cent, ginger rhizome extract (GRE) 5 per cent and control (no spray) along with three repetitions

with a view to evaluate bio-efficacy of various biopesticides against *A. atkinsoni.* Existing trees of mango cv. Langra at a spacing of 10 × 10 m having equal age, canopy and growth were selected. Treatment wise application of biopesticides were given at ETL (5 hoppers/panicle) on the trees by using foot sprayer with required concentration. Subsequently two sprays were given at 10 days interval. The observations were recorded before spraying as well as 1, 3, 5, 7 and 10 days after each spray from 5 randomly selected panicles or inflorescences from each direction from each tree. The data obtained were analyzed by following standard statistical technique (Steel and Torrie, 1980) [10].

Results and Discussion

The population of hoppers was homogeneous before spray in all the treatments as treatments did not differ significantly. All the evaluated biopesticides were significantly superior to control up to 10 days of spray.

First spray

One day after the first spray (Table 1), the lowest (5.44 hoppers/panicle) population of mango hoppers was found with the treatment of NSKE 5 per cent which was at par with *L. lecanii*, neem oil and NLE with the population of 5.53, 5.75 and 5.88 mango hoppers per panicle, respectively. While, the highest (9.14/panicle) mango hoppers population was found from trees treated with GBE which was at par *B. bassiana* (8.69/panicle), *M. anisopliae* (8.89/panicle) and GRE (8.91/panicle). More or less similar trend in efficacy was observed at three days after first spray.

Minimum mango hoppers were recorded (4.75/panicle) from the trees treated with NSKE, *L. lecanii* (4.93/panicle), neem oil (5.25/panicle) and NLE (5.40/panicle) after five days of the spray. Of the biopesticides evaluated, maximum (9.05/panicle) population of hoppers was noticed from trees sprayed with GBE which was at par with *B. bassiana* (8.00/panicle), *M. anisopliae* (8.25/panicle) and GRE (8.76/panicle). More or less similar results were obtained at seven days after first spray.

At ten days after the first spray, NSKE (4.67/panicle), *L. lecanii* (4.76/panicle), neem oil (5.03/panicle) and NLE (5.19/panicle) proved most effective and found at par with each other. While, the treatments of *B. bassiana* (8.17/panicle), *M. anisopliae* (8.34/panicle), GRE (9.71/panicle) and GBE (9.82/panicle) exhibited comparatively less effectiveness against hoppers.

Pooled over periods data (Table 1) of the first spray revealed that NSKE (4.83/panicle), *L. lecanii* (4.96/panicle), neem oil (5.21/panicle) and NLE (5.34/panicle) found significantly superior than rest of the evaluated biopesticidal treatments. The trees treated with GBE recorded the highest (9.14/panicle) hopper population which was at par with *B. bassiana* (8.11/panicle), *M. anisopliae* (8.32/panicle) and GRE (8.98/panicle).

Second spray

The data of first day (Table 2) revealed that NSKE (3.97/panicle), *L. lecanii* (4.07/panicle), neem oil (4.26/panicle) and NLE (4.37/panicle) proved effective in reducing the population of hoppers. Trees with the treatment of GRE recorded the maximum (9.79/panicle) population of mango hoppers which was at par with *B. bassiana* (7.00/panicle), *M. anisopliae* (7.12/panicle) and GBE (9.68/panicle). The lowest (3.55/panicle) population of hoppers was noticed on trees treated with NSKE which was at par with *L. lecanii* (3.67/panicle), neem oil (3.91/panicle) and NLE (4.03/panicle) after three days. The trees treated with *B. bassiana* (6.28/panicle) also recorded significantly lower population of hoppers than rest of the treatments and stood at par with *M. anisopliae* (6.35/panicle). Of the evaluated biopesticides, maximum (9.33/panicle) hopper population was observed on trees treated with GRE and it was at par with GBE (9.26/panicle). More or less similar results were observed at five days after second spray.

The treatments of *L. lecanii*, NSKE, neem oil and NLE found effective against *A. atkinsoni* at seven days after second spray by registering the incidence as 3.00, 3.10, 3.42 and 3.49 hoppers per panicle, respectively. *B. bassiana* (5.64/panicle) and *M. anisopliae* (5.79/panicle) treated trees exhibited significantly lower incidence of hoppers at seven days after the second spray as compared to the remaining treatments. Among the different biopesticides tested, maximum (8.57/panicle) hoppers were recorded in the treatment of GRE, which was at par with GBE (8.37/panicle). More or less analogous trend in efficacy was observed at 10 days after second spray.

Pooled over period data (Table 2) indicated that, the lowest (3.46/panicle) hopper population was recorded from the treatment of NSKE which was at par with *L. lecanii* (3.55/panicle), neem oil (3.83/panicle) and NLE (3.94/panicle). These treatments proved significantly superior to the remaining treatments. The trees sprayed with *B. bassiana* (6.21/panicle) and *M. anisopliae* 6.43/panicle) also registered significantly lower population of hoppers than rest of the treatments. The highest (9.14/panicle) population of hoppers was recorded on the trees treated with GRE and it was at par with GBE (9.05/panicle).

Third spray

The least (2.55/panicle) hopper incidence was observed in trees treated with *L. lecanii* which was at par with treatments of NSKE (2.64/panicle), neem oil (2.75/panicle) and NLE (2.88/panicle) at one day after third spray (Table 3). These four biopesticidal treatments found significantly superior to other treatments. *B. bassiana* and *M.* treated trees recorded significantly lower hopper population of 5.22 and 5.31/ panicle, respectively than the remaining treatments. Amid the tested biopesticides, maximum (8.35/panicle) hopper population was recorded from the trees treated with GRE and it was at par with GBE (8.09/panicle). Similar trend in efficacy of different biopesticides was observed at three days after third spray.

Hopper population recorded at five days after third spray, revealed that NSKE (1.62/panicle) was found the most effective followed by *L. lecanii* (1.69/panicle), neem oil (1.81/panicle) and NLE (1.89/panicle). Moreover, the trees with the application of *B. bassiana* (3.57/panicle) and *M. anisopliae* (3.58/panicle) exhibited significant effect on population of hoppers. The treatments of GBE (5.76/panicle) and GRE (5.93/panicle) were less effective against hoppers.

Seven days after spray, NSKE and *L. lecanii* registered the lowest (1.12 & 1.17/panicle, respectively) incidence of *A. atkinsoni* which was at par with neem oil (1.27/panicle) and NLE (1.34/panicle). Significant effect of *B. bassiana* (2.58/panicle) and *M. anisopliae* (2.74/panicle) was noticed on hopper population. The trees treated with GRE recorded the highest (4.53/panicle) hopper population and it was at par with GBE (4.41/panicle). More or less similar results were observed at ten days after third spray.

The data of pooled over periods (Table 4.5) of the third spray asserted that NSKE (1.59/panicle), *L. lecanii* (1.61/panicle), neem oil (1.78/panicle) and NLE (1.90/panicle) found significantly superior to the evaluated biopesticides. The treatments of *B. bassiana* (3.47/panicle) and *M. anisopliae* (3.62/panicle) provided significant reduction in population of *A. atkinsoni*. The trees treated with GRE recorded the highest (5.76/panicle) number of hoppers and it was at par with GBE (5.60/panicle).

Overall pooled

Overall data (Table 3 and Figure 1) revealed that NSKE (3.17/panicle) proved superior than all the evaluated biopesticides except *L. lecanii* (3.24/panicle), neem oil (3.48/panicle) and NLE (3.59/panicle). *Beauveria bassiana* (5.78/panicle) and *M. anisopliae* (5.94/panicle) treated trees revealed significantly lower incidence of hoppers. The trees treated with GRE recorded the maximum (7.88/panicle) *A. atkinsoni* population and it was at par with GBE (7.84/panicle).

Effect on mango fruit yield

The mango fruit yield data were recorded in various biopesticidal treatments as well as in control during study and are presented in Table 4 and depicted in Figure 2.

Maximum (118.77 q/ha) mango fruit yield was harvested from the trees treated with NSKE which was at par with *L. lecanii* (116.27 q/ha), neem oil (110.79 q/ha) and NLE (108.03 q/ha). These four biopesticides were found to be relatively more effective which reflected on yield of mango fruits. Among the various biopesticides, the lowest (80.68 q/ha) yield of mango fruits was recorded from the trees treated with GRE which was at par with *B. bassiana* (94.57 q/ha) and *M. anisopliae* (88.04 /ha), GBE (83.29 /ha).

Increase in yield over control was worked out for different biopesticidal treatments which indicated that maximum (49.25%) increase in was yield found from trees treated with NSKE followed by *L. lecanii* (48.15%), neem oil (45.59%) and NLE (44.20%).

Economics

Economics of various biopesticides evaluated against mango hopper, *A. atkinsoni* indicated that the highest (1: 13.16) return was obtained with the treatment of NSKE followed by *L. lecanii* (1: 12.56), neem oil (1: 11.23) and NLE (1: 10.56). The NICBR of 1: 7.30, 1: 5.72 and 1: 4.57 was registered in the treatments of *B. bassiana M. anisopliae* and GBE, respectively. The lowest NICBR (1: 3.94) was recorded in the treatment of GRE.

According to Chaudhari *et al.* (2017) [3] neem oil 1 per cent was effective with a mean mortality ranging 79.71 – 66.40 per cent. *L. lecanii* 1.15 WP was found superior in controlling the mango hoppers with a mean mortality of 86.04 and 71.99 per cent during I and II spray, respectively under field conditions. Sarode and Mohite (2016) [7] reported that *M. anisopliae*, *V. lecanii*, *B. bassiana* and NSKE were found equally effective in reducing population of mango hoppers. As per the report of Singh (2008) [8] application of *L. lecanii* at the dose of 5 g/L had lower hopper population of 1.7 per panicle. It was also concluded that neem based neem seed kernel extract at 5 per cent or neem oil at 0.5 per cent found effective for the management of mango hoppers, *A. atkinsoni* under middle Gujarat conditions (Anon., 2006) [1]. Thus, these reports are in agreement with the present findings.

Table 1: Bio-efficacy of insecticides against hoppers, *A. atkinsoni* infesting mango after second spray

Tr. No.	Treatments	Conc. in%	No. of hoppers/ panicle days after spray						
			Before spray	1	3	5	7	10	Pooled over periods
T_1	Neem seed kernel extract	5.0	3.20a (9.75)	2.44c (5.44)	2.35e (5.00)	2.29e (4.75)	2.20d (4.34)	2.27d (4.67)	2.31c (4.83)
T_2	Neem oil	0.5	3.01a (8.55)	2.50c (5.75)	2.41de (5.32)	2.40de (5.25)	2.28cd (4.72)	2.35d (5.03)	2.39c (5.21)
T_3	Neem leaf extract	10.0	3.15a (9.40)	2.53c (5.88)	2.43cde (5.42)	2.43cde (5.40)	2.30cd (4.80)	2.39cd (5.19)	2.42c (5.34)
T_4	Garlic bulb extract	5.0	3.21a (9.77)	3.11ab (9.14)	3.10ab (9.13)	3.09ab (9.05)	3.03ab (8.70)	3.19d (9.71)	3.11b (9.14)
T_5	Ginger rhizome extract	5.0	3.08a (8.99)	3.07ab (8.91)	3.07ab (8.90)	3.04b (8.76)	2.99b (8.46)	3.21ab (9.82)	3.08b (8.98)
T_6	*Beauveria bassiana* 5% WP (1 x 10^9 cfu/g)	0.4	3.13a (9.27)	3.03b (8.69)	2.99bcd (8.45)	2.92bcd (8.00)	2.79bc (7.29)	2.95bc (8.17)	2.93b (8.11)
T_7	*Lecanicillium lecanii* 1.15% WP (1 x 10^9 cfu/g)	0.4	3.22a (9.89)	2.46c (5.53)	2.37e (5.13)	2.33e (4.93)	2.23d (4.48)	2.29d (4.76)	2.34c (4.96)
T_8	*Metarhizium anisopliae* 1.15% WP (1 x 10^9 cfu/g)	0.4	3.28a (10.26)	3.07ab (8.89)	3.02bc (8.61)	2.96bc (8.25)	2.83b (7.51)	2.97bc (8.34)	2.97b (8.32)
T_9	Control	-	3.29a (10.34)	3.57a (12.21)	3.67a (12.94)	3.62a (12.58)	3.53a (11.95)	3.60a (12.49)	3.60a (12.43)
S. Em. ± T		-	0.17	0.18	0.16	0.16	0.18	0.18	0.07
P		-	-	-	-	-	-	-	0.05
T x P		-	-	-	-	-	-	-	0.17
C.V.%		-	9.12	9.33	11.08	9.98	10.06	10.95	10.30

Notes: Figures in parentheses are retransformed values of $\sqrt{x+0.5}$

Treatment mean with letter(s) in common are non-significant by DNMRT at 5% level of significance

Table 2: Bio-efficacy of insecticides against hoppers, *A. atkinsoni* infesting mango after second spray

Tr. No.	Treatments	Conc. in%	No. of hoppers/ panicle days after spray					
			1	3	5	7	10	Pooled over periods
T_1	Neem seed kernel extract	5.0	2.12e (3.97)	2.01c (3.55)	1.97d (3.39)	1.90f (3.10)	1.95d (3.29)	1.99d (3.46)
T_2	Neem oil	0.5	2.18de (4.26)	2.10c (3.91)	2.05d (3.69)	1.98ef (3.42)	2.10d (3.89)	2.08d (3.83)
T_3	Neem leaf extract	10.0	2.21cde (4.37)	2.13bc (4.03)	2.08cd (3.82)	2.00def (3.49)	2.12d (3.99)	2.11d (3.94)
T_4	Garlic bulb extract	5.0	3.19ab (9.68)	3.12a (9.26)	3.09ab (9.03)	2.98bc (8.37)	3.07b (8.94)	3.09b (9.05)
T_5	Ginger rhizome extract	5.0	3.21ab (9.79)	3.14a (9.33)	3.07ab (8.93)	3.01ab (8.57)	3.10b (9.12)	3.11b (9.14)
T_6	*Beauveria bassiana* 5% WP (1 x 10^9	0.4	2.74bcd (7.00)	2.60b (6.28)	2.57bc (6.10)	2.48cde (5.64)	2.56c (6.06)	2.59c (6.21)

	cfu/g)							
T_7	*Lecanicillium lecanii* 1.15% WP (1 x 10^9 cfu/g)	0.4	2.14e (4.07)	2.04c (3.67)	2.00d (3.50)	1.87f (3.00)	2.02d (3.56)	2.01d (3.55)
T_8	*Metarhizium anisopliae* 1.15% WP (1 x 10^9 cfu/g)	0.4	2.76bc (7.12)	2.62b (6.35)	2.59bc (6.19)	2.51bcd (5.79)	2.60c (6.27)	2.61c (6.34)
T_9	Control	-	3.76a (13.64)	3.61a (12.56)	3.58a (12.29)	3.53a (11.98)	3.53a (11.95)	3.60a (12.48)
S. Em. ± T		-	0.17	0.15	0.16	0.16	0.14	0.07
P		-	-	-	-	-	-	0.05
T x P		-	-	-	-	-	-	0.15
C.V.%		-	11.15	10.00	10.48	11.01	9.44	10.45

Notes: Figures in parentheses are retransformed values of $\sqrt{x+0.5}$ Treatment mean with letter(s) in common are non-significant by DNMRT at 5% level of significance

Table 3: Bio-efficacy of insecticides against hoppers, *A. atkinsoni* infesting mango after second spray

Tr. No.	Treatments	Conc. in%	No. of hoppers/ panicle days after spray						
			1	3	5	7	10	Pooled over periods	Pooled over periods and sprays
T_1	Neem seed kernel extract	5.0	1.77e (2.64)	1.66e (2.24)	1.46e (1.62)	1.27d (1.12)	1.08e (0.66)	1.45d (1.59)	1.92d (3.17)
T_2	Neem oil	0.5	1.80e (2.75)	1.69de (2.36)	1.52e (1.81)	1.33d (1.27)	1.21e (0.96)	1.51d (1.78)	1.99d (3.48)
T_3	Neem leaf extract	10.0	1.84de (2.88)	1.71de (2.42)	1.55de (1.89)	1.36d (1.34)	1.29e (1.16)	1.55d (1.90)	2.02d (3.59)
T_4	Garlic bulb extract	5.0	2.93bc (8.09)	2.63b (6.42)	2.50b (5.76)	2.22b (4.41)	2.07bc (3.78)	2.47b (5.60)	2.89b (7.84)
T_5	Ginger rhizome extract	5.0	2.98b (8.35)	2.65b (6.51)	2.54b (5.93)	2.24b (4.53)	2.10b (3.93)	2.50b (5.76)	2.90b (7.88)
T_6	*Beauveria bassiana* 5% WP (1 x 10^9 cfu/g)	0.4	2.39cd (5.22)	2.15cd (4.17)	1.99cd (3.57)	1.76c (2.58)	1.67d (2.29)	1.99c (3.47)	2.51c (5.78)
T_7	*Lecanicillium lecanii* 1.15% WP (1 x 10^9 cfu/g)	0.4	1.75e (2.55)	1.63e (2.14)	1.48e (1.69)	1.29d (1.17)	1.12e (0.75)	1.45d (1.61)	1.93d (3.24)
T_8	*Metarhizium anisopliae* 1.15% WP (1 x 10^9 cfu/g)	0.4	2.41bc (5.31)	2.19bc (4.30)	2.02c (3.58)	1.80c (2.74)	1.73cd (2.50)	2.03c (3.62)	2.54c (5.94)
T_9	Control	-	3.62a (12.60)	3.67a (12.96)	3.47a (11.52)	3.52a (11.90)	3.58a (12.35)	3.57a (12.26)	3.59a (12.39)
S. Em. ± T		-	0.17	0.14	0.14	0.12	0.10	0.06	0.04
P		-	-	-	-	-	-	0.05	0.03
T x P		-	-	-	-	-	-	0.14	0.09
C.V.%		-	12.33	11.08	11.72	11.10	10.14	11.50	10.72

Notes: Figures in parentheses are retransformed values of $\sqrt{x+0.5}$ Treatment mean with letter(s) in common are non-significant by DNMRT at 5% level of significance

Table 4: Effect of various insecticide on mango fruit yield

Sr. No.	Treatments	Yield (q/ha)	Increase in yield over control (%)
T_1	Neem seed kernel extract	118.77a	49.25
T_2	Neem oil	110.79ab	45.59
T_3	Neem leaf extract	108.03abc	44.20
T_4	Garlic bulb extract	83.29d	27.63
T_5	Ginger rhizome extract	80.68d	25.29
T_6	*Beauveria bassiana* 5% WP (1 x 10^9 cfu/g)	94.57bcd	36.26
T_7	*Lecanicillium lecanii* 1.15% WP (1 x 10^9 cfu/g)	116.27ab	48.15
T_8	*Metarhizium anisopliae* 1.15% WP (1 x 10^9 cfu/g)	88.04cd	31.53
T_9	Control	60.28e	-
S. Em. +		6.77	-
C. V. (%)		10.34	-

Note: Treatment mean with letter(s) in common are non-significant by DNMRT at 5% level of significance

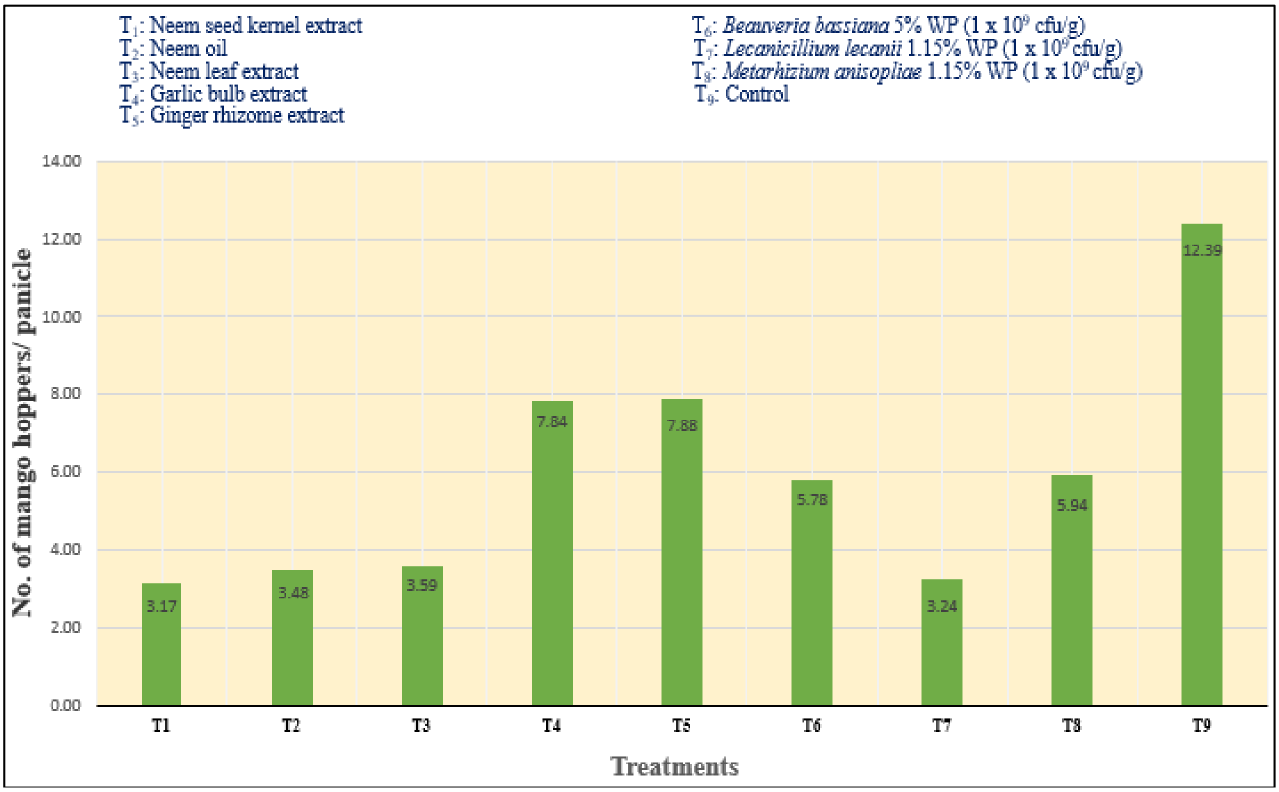

Fig 1: Bio-efficacy of different biopesticides against hoppers, *A. atkinsoni* infesting mango (Pooled over sprays)

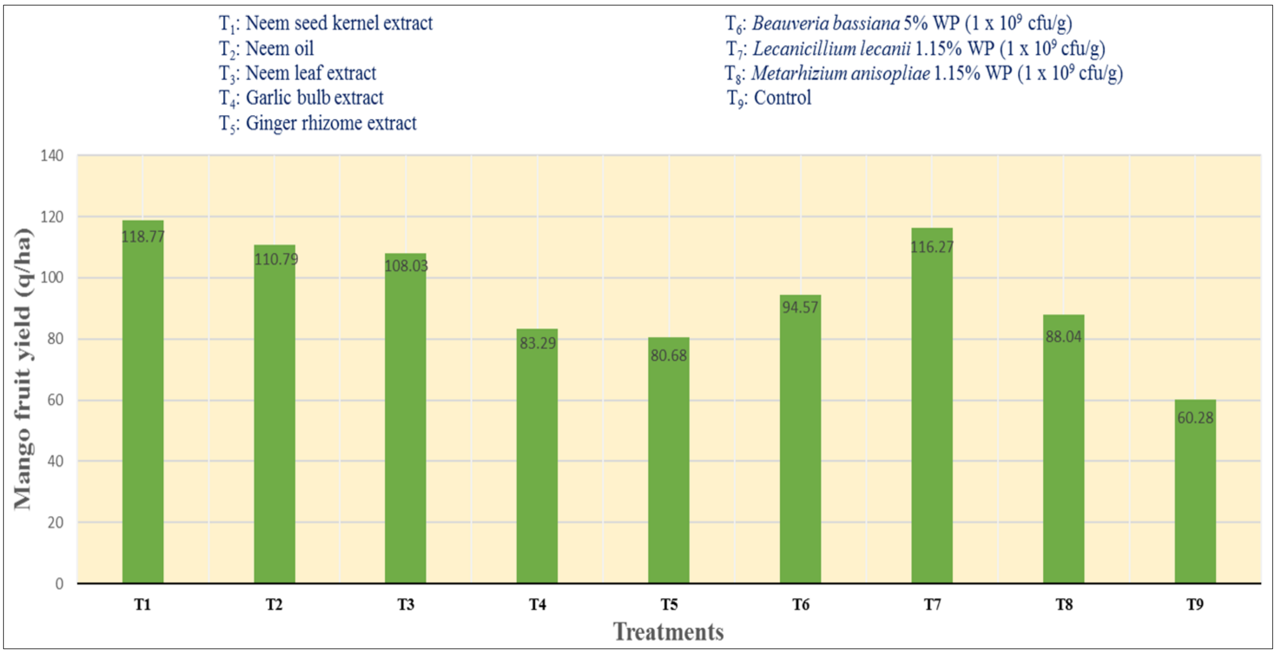

Fig 2: Effect of different insecticidal treatments on mango fruit yield

Conclusion

In nutshell, of the eight biopesticides, application of neem seed kernel extract found the most effective followed by *L. lecanii*, neem oil and neem leaf extract with mango fruit yield 118.77, 116.27, 110.79 and 108.03 q/ha, respectively. Looking to the NICBR, the highest (1: 13.16) return obtained with the treatment of NSKE followed by *L. lecanii* (1: 12.56) neem oil (1: 11.23) and neem leaf extract (1: 10.56).

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