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To evaluate the efficacy of different biopesticides against mango leaf hoppers

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Abstract
Present investigation entitled "Varietal preference of mango leaf hoppers and its management through biopesticides" was conducted at the Horticultural mango orchard, B.T.C. College of agriculture and research station, Bilaspur, Chhattisgarh during November-2020 to May-2021.

Among the insecticide's treatments in first spray, the Imidacloprid was found most effective to controlling leaf hoppers with least leaf hopper population (3.04/twig/panicle) followed by Azadirachtin (7.49/twig/panicle) and Neem oil (9.27/twig/panicle). Among microbial treatments *Verticillium lecanii* was found most effective with minimum leaf hopper population (10.66/twig/panicle) followed by *Metarhizium anisoplae* (11.71/twig/panicle) and maximum leaf hopper population was recorded in treatment of *Beauveria bassiana* (12.64/twig/panicle). The untreated control showed significantly highest leaf hopper population (19.33/twig/panicle).

In second spray, the imidacloprid was found most effective to controlling leaf hoppers with least population (2.47/twig/panicle) followed by Azadirachtin (6.96/twig/panicle) and Neem oil (8.65/twig/panicle). Among microbial treatments *Verticillium lecanii* was found most effective with minimum hopper population (9.30/twig/panicle) followed by *Metarhizium anisoplae* (10.26/twig/panicle) and maximum hopper population was recorded in treatment of *Beauveria bassiana* (10.56/twig/panicle). The untreated control showed significantly highest hopper population (13.85/twig/panicle).

Keywords: Mango leaf hopper, bio-efficacy, insecticide, microbial, azadirachtin, neem oil, *Metarhizium anisoplae, Verticillium lecanii*. *Beauveria bassiana*

Introduction
Mango (*Mangifera indica* L.) holds a vital position in India as a significant fruit crop, thriving in both tropical and sub-tropical climates. India has a rich history of cultivating mangoes for over 4,000 years, earning it the title of the "Pride of Fruits." In the Indian context, mango is not just the national fruit but is also known as the "King of Fruits" due to its delectable taste, aromatic flavor, high nutritional value, appealing color, and widespread popularity. Mango fruit stands as a cornerstone of tropical fruit, much like apples in temperate regions. It belongs to the Mangifera genus and boasts various applications, from using immature green mangoes to prepare chutney, pickles, and Amchoor in Chhattisgarh, to creating beverages like nectars, syrups, and jellies from ripe mangoes. In times of food scarcity, mango seeds, also known as 'Stones,' can be consumed. Mango wood serves diverse purposes, including furniture, boat construction, and home flooring. Beyond its utility, mangoes are a rich source of essential nutrients, including Vitamins A, B complex, C, minerals, digestible sugars, and micronutrients. Ripe mango flesh is incredibly sweet, with around 10-15% digestible sugars and 1% protein, while green mangoes contain approximately 81.6% water, along with 0.5% proteins, 0.3% fat, and 0.5% ash per 100 grams, totaling about 65 calories. Mangoes have been associated with various health benefits, including aiding blood clotting, supporting heart health, and benefiting brain function. Fresh mangoes and pulps are agriculturally significant for export purposes. Mango seeds, containing 9-10% unsaturated fat, are useful for making soap.

On a global scale, India, China, Pakistan, Mexico, Thailand, Indonesia, Brazil, and the Philippines are prominent mango-producing countries. India, in particular, leads the world in mango production, with data from 2017-18 indicating an area of 2,258 million hectares dedicated to mango cultivation and a production of 21,822 million tons (Anonymous, 2018) [1]. Mango trees are susceptible to recurring losses due to pest infestations, posing a significant threat to the mango industry.

Mango trees can be attacked by approximately 492 species of insects, 26 species of nematodes, and 17 species of mites globally. Among these, India has reported 188 insect species (Verghese and Tandon, 1985) [16].

Mango orchards are vulnerable to various insect pests, with hopper infestation being a major factor limiting yield and affecting fruit quality. Three key species of mango hoppers, A. atkinsoni, I. clypealis, and I. niveosparsus, are noteworthy, with A. atkinsoni being the most predominant species in southern Andhra Pradesh (Bhaskar, 2007) [4]. These mango hoppers primarily feed on sap from tender shoots, leaves, and inflorescences, leading to the shriveling of panicles, which turn brown and eventually fall off. The hoppers excrete honeydew, causing sooty mold on the leaves. Under heavy infestations, affected panicles may not set fruit, resulting in potential yield losses of up to 100% (Butani, 1979; Sohi, 1990; Rahman and Kuldeep, 2007) [3, 13, 12]. The activity of leaf hoppers peaks during the emergence of new shoots and inflorescences in mango trees (Zagade and Chaudhari, 2010) [17]. Mango hopper nymphs and adults feed on sap from tender leaves, buds, flowers, panicles, and fruits by sucking. In cases of heavy infestation, leaves become twisted, and inflorescences dry up, a condition referred to as hopper burn.

Materials and Methods

To evaluate the efficacy of bio pesticides against mango leaf hoppers, field trials were conducted during December-May 2020-21 at the Horticultural orchard, BTC College of Agriculture and Research Station, Bilaspur (Chhattisgarh) with seven treatments, replicated thrice in Randomized Block Design. Twenty-one trees of mango (CV Dashehari) were randomly selected and tagged; the insecticidal treatments were applied with the help of rocker sprayer at Economic threshold level (5-10 hopper/twigs) on these trees when the pest population reaches between 5-10 hoppers/twig/panicle. The pre and post treatment observations were recorded before twenty-four hour and after 3rd, 5th, 7th and 15th days of insecticide spray, respectively. The hopper population was recorded on randomly selected and tagged twelve/panicle i.e., three panicles in each direction (North, South, East, and West) per branch in each tree. The sample size of each panicle was ten to twelve cm. The pre-treatment hopper counts along with the post treatment population reduction were transformed and subjected to statistical analysis for result interpretation.

Results and Discussion

A study titled "To evaluate the efficacy of different biopesticides against mango leaf hoppers" was carried out. In this study, different biopesticides were evaluated, including Imidacloprid 17.8 SL at a rate of 1.25 ml, Azadirachtin 1% EC at 15 ml, Neem oil 0.5% at 25 ml, *Verticillium lecanii* 10% WP at 50 gm, *Metarhizium anisoplae* 10% WP at 50 gm, *Beauveria bassiana* 10% WP at 50 gm per tree, and an untreated control.

Insecticide Spraying: The assessment involved two rounds of insecticide application, and data were collected at intervals of 3rd, 5th, 7th, and 15th days after each spraying.

First Insecticide Spray: Before the initial insecticide application, the population of hoppers per panicle was recorded, ranging from 17.26 to 17.70, and the uniform distribution of the pest among the different treatments was statistically insignificant. Subsequent observations of hopper populations were recorded at 3rd, 5th, 7th, and 15th days after spraying, as outlined in Table 1.

The data revealed that three days after the spray, the average hopper population varied from 1.46 to 18.8 per panicle in different treatments. Imidacloprid was the most effective, with the lowest hopper population (1.46), followed by Azadirachtin (7.66), Neem oil (9.72), *Verticillium lecanii* (10.55), *Metarhizium anisoplae* (11.08), and *Beauveria bassiana* (12.33). All biopesticide treatments were significantly more effective than the untreated control. In terms of effectiveness against mango leaf hoppers three days after spraying, the order is as follows: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria.*

Five days after insecticide spraying, the average hopper population ranged from 1.36 to 20.00 per panicle. Again, Imidacloprid showed the lowest population of hoppers (1.36), followed by Azadirachtin (6.52), Neem oil (6.63), *Verticillium lecanii* (9.47), *Metarhizium anisoplae* (10.74), and *Beauveria bassiana* (11.57). All treatments were significantly more effective than the untreated control (20.00). The order of effectiveness in terms of hopper population five days after spraying is: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria*.

After seven days of spraying, the average hopper population ranged from 1.83 to 22.63 per panicle. Imidacloprid, once again, exhibited the lowest population of hoppers (1.83), followed by Azadirachtin (6.75), Neem oil (8.50), *Verticillium lecanii* (9.86), *Metarhizium anisoplae* (11.25), and *Beauveria bassiana* (12.00). The untreated control recorded the significantly highest hopper population (22.63). The order of effectiveness in terms of hopper population seven days after spraying is: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria*.

Fifteen days after spraying, the average hopper population ranged from 7.50 to 15.88 per panicle. Imidacloprid again showed the lowest population of hoppers (7.50), followed by Azadirachtin (9.00), Neem oil (12.22), *Verticillium lecanii* (12.75), *Metarhizium anisoplae* (13.75), and *Beauveria bassiana* (14.66). The untreated control recorded the significantly highest hopper population (15.88). The order of effectiveness in terms of hopper population fifteen days after spraying is: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria.*

Overall, the average hopper population in all insecticide treatments tested for their effectiveness against the pest was significantly lower than in the untreated control. The mean population of hoppers based on post-treatment observations ranged from 3.04 to 19.33 per panicle in different treatments. Imidacloprid was the most effective, with the lowest hopper population (3.04), followed by Azadirachtin (7.49), Neem oil (9.27), *Verticillium lecanii* (10.66), *Metarhizium anisoplae* (11.71), and *Beauveria bassiana* (12.64). The untreated control had the highest hopper population (19.33 per panicle). The order of effectiveness against mango leaf hoppers, based on overall observations, is: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria*.

Table 1: Evaluation of biopesticides against mango leaf hoppers (var. Dashehari) during 2021

First insecticide spraying							
Average population of mango leaf hoppers (no./panicle)							
S. No.	**Treatment**	**Pre-Treatment population**	**3 DAS**	**5 DAS**	**7 DAS**	**15 DAS**	**Post treatment Mean**
1	Imidacloprid 17.8 SL	17.7 (4.32)	1.46 (1.57)	1.36 (1.52)	1.83 (1.68)	7.5 (2.88)	3.04 (1.92)
2	Azadirachtin 1EC	17.5 (4.30)	7.66 (2.92)	6.52 (2.73)	6.75 (2.78)	9 (3.14)	7.49 (2.90)
3	Neem oil 0.5%	17.4 (4.29)	9.72 (3.26)	6.63 (2.76)	8.5 (3.08)	12.22 (3.63)	9.27 (3.18)
4	*Verticillium lecanii* 10% WP (1×10^7 CFU/gm)	17.3 (4.28)	10.55 (3.40)	9.47 (3.23)	9.86 (3.29)	12.75 (3.68)	10.66 (3.41)
5	*Metarrhizium anisopliae* 10% WP(1×10^7 CFU/gm)	17.4 (4.29)	11.08 (3.47)	10.74 (3.41)	11.25 (3.49)	13.75 (3.84)	11.71 (3.56)
6	*Beauveria bassiana* 10% WP (1×10^7 CFU/gm)	17.26 (4.27)	12.33 (3.64)	11.57 (3.54)	12 (3.59)	14.66 (3.96)	12.64 (3.69)
7	Untreated Control	17.6 (4.31)	18.8 (4.45)	20 (3.82)	22.63 (4.86)	15.88 (4.11)	19.33 (4.5)
	SEm±	0.01	0.17	0.13	0.14	0.19	0.15
	CD at 5%	NS	0.46	0.41	0.20	0.59	0.44

Note: Figure in parentheses is square root transformed value DAS: Days after spraying

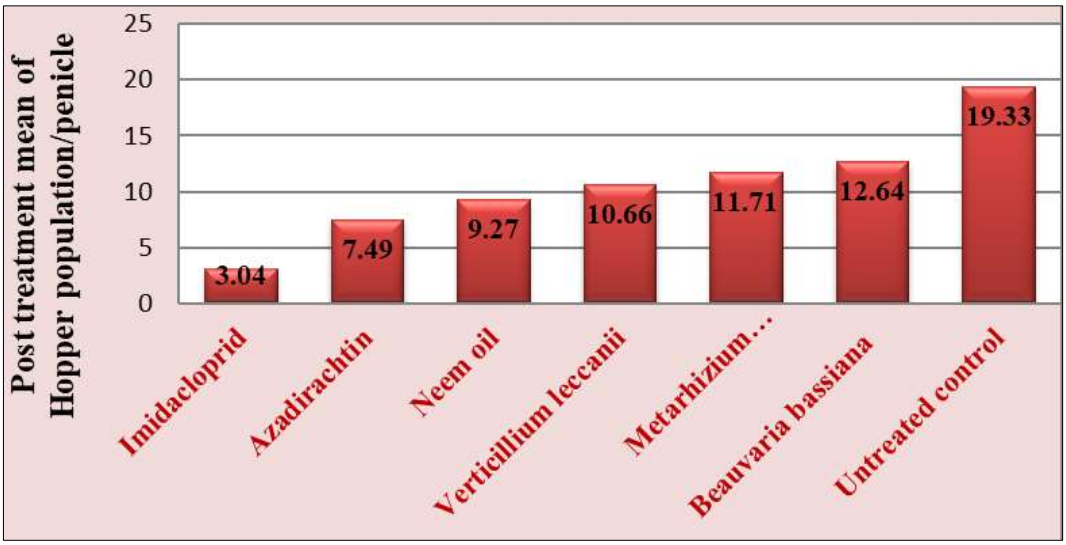

Fig 2: Bio-efficacy of biopesticides against leaf hoppers on mango after First spray at Bilaspur during 2020-21

Second spray of insecticide

The initial observation of hopper populations during the second spray ranged from 11.26 to 12.50 per panicle, and these numbers were statistically insignificant, indicating a uniform distribution of the pests among the different treatments. Subsequent observations of hopper populations were recorded at 3rd, 5th, 7th, and 15th days after spraying, as detailed in Table 2.

After three days following the spray, the average hopper populations varied from 1.41 to 21.91 per panicle across different treatments. Imidacloprid exhibited the lowest population of hoppers (1.41), making it the most effective against mango leaf hoppers, followed by Azadirachtin (7.33), Neem oil (8.5), *Verticillium lecanii* (8.58), *Metarhizium anisopliae* (10.50), and *Beauveria bassiana* (11.02). All the biopesticidal treatments significantly outperformed the untreated control. The order of effectiveness against mango leaf hoppers three days after spraying was as follows: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria.*

Five days after the insecticide application, the average hopper populations ranged from 1.33 to 9.91 per panicle. Imidacloprid once again showed the lowest hopper population (1.33) and was most effective against mango leaf hoppers, followed by Azadirachtin (6.41), Neem oil (6.58), *Verticillium lecan*ii (8.52), *Metarhizium anisoplae* (9.00), and *Beauveria bassiana* (9.33). All treatments were significantly more effective than the untreated control (9.91). The order of effectiveness in terms of hopper population five days after spraying was: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria*.

At seven days following the insecticide spray, the average hopper populations ranged from 1.50 to 11.17 per panicle. Imidacloprid exhibited the lowest population of hoppers (1.50), followed by Azadirachtin (6.55), Neem oil (8.19), *Verticillium lecanii* (8.55), *Metarhizium anisopliae* (9.55), and *Beauveria bassiana* (9.72). Although *Beauveria bassiana* had a significantly higher hopper population (9.72) compared to other microbial insecticide treatments, it was still superior to the control. The untreated control had the highest hopper population (11.17). The order of effectiveness in terms of hopper population seven days after spraying was: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria.*

Fifteen days after the spray, the average hopper populations ranged from 5.66 to 12.41 per panicle. Imidacloprid exhibited the lowest population of hoppers (5.66), followed by Azadirachtin (7.55), Neem oil (11.33), *Verticillium lecanii* (11.55), *Metarhizium anisoplae* (12.00), and *Beauveria bassiana* (12.20). However, a higher population of hoppers was observed in the untreated control (13.85). The order of effectiveness in terms of hopper population fifteen days after spraying was: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria*.

Overall, the average leaf hopper populations in all the insecticide treatments tested for their efficacy against the pest were significantly lower than in the untreated control. The mean population of hoppers based on overall post-treatment observations ranged from 2.47 to 13.85 per panicle in different treatments. Imidacloprid was the most effective, with the lowest hopper population (2.47), followed by Azadirachtin (6.96), Neem oil (8.65), *Verticillium lecanii* (9.3), *Metarhizium anisoplae* (10.26), and *Beauveria bassiana* (10.56). In contrast, the untreated control had the highest hopper population (13.85 per panicle). The order of effectiveness against mango leaf hoppers, based on overall observations, was: Imidacloprid < Azadirachtin < Neem oil < *Verticillium* < *Metarhizium* < *Beauveria.*

These findings align with previous research, such as Girish *et al*. (2019) [3], which declared Imidacloprid as the most effective in reducing mango hopper populations on mango. Additionally, the results are in agreement with Kaushik *et al.* (2014) [4], who reported that Imidacloprid was the most effective and significantly superior in reducing hopper populations. Other studies, including Sarode and Mohite (2016) [10], Ray *et al*. (2011) [8], Singh *et al*. (2010) [9], Kumar *et al.* (2005), also reported Imidacloprid as the most effective treatment for reducing hopper populations on mango. Girish *et al.* (2019) [3] observed that *Vericillium lecanii*, *Metarhizium anisoplae,* and Beauveria bassiana were equally effective in reducing the population of *A. atkinsoni* by registering lower numbers of hoppers (1.74 - 2.38 per inflorescence). In this study, *Beauveria bassiana* was found to be the least effective microbial insecticide treatment in controlling hopper populations on mango, which is consistent with the findings of Girish *et al.* (2019) [3], who also reported that *Beauveria bassiana* was less effective in controlling hopper populations among microbial treatments.

Table 2: Evaluation of biopesticides against mango leaf hoppers (var. Dashehari) during 2021

Second insecticide spraying							
Average population of mango leaf hoppers (no./panicle)							
S. No.	**Treatment**	**Pre-treatment population**	**3 DAS**	**5 DAS**	**7 DAS**	**15 DAS**	**Post treatment Mean**
1	Imidacloprid 17.8 SL	11.00 (3.46)	1.41 (1.58)	1.33 (1.52)	1.5 (1.57)	5.66 (2.58)	2.47 (1.81)
2	Azadirachtin 1EC	11.46 (3.53)	7.33 (2.91)	6.41 (2.72)	6.55 (2.73)	7.55 (2.92)	6.96 (2.82)
3	Neem oil 0.5%	11.55 (3.54)	8.5 (3.15)	6.58 (2.75)	8.19 (3.02)	11.33 (3.50)	8.65 (3.09)
4	*Verticillium lecanii* 10% WP (1×10^7 CFU/gm)	11.65 (3.55)	8.58 (3.09)	8.52 (3.08)	8.55 (3.10)	11.55 (3.54)	9.3 (3.20)
5	*Metarrhizium anisopliae* 10% WP(1×10^7 CFU/gm)	11.70 (3.56)	10.5 (3.37)	9 (3.14)	9.55 (3.23)	12 (3.60)	10.26 (3.35)
6	*Beauveria bassiana* 10% WP (1×10^7 CFU/gm)	11.80 (3.57)	11.02 (3.46)	9.33 (3.19)	9.72 (3.48)	12.2 (3.61)	10.56 (3.39)
7	Untreated Control	12.5 (3.67)	21.91 (4.78)	9.91 (3.30)	11.17 (3.07)	12.41 (2.38)	13.85 (3.81)
	SEm±	0.048	0.31	0.21	0.11	0.14	0.15
	CD at 5%	NS	0.40	0.37	0.36	0.44	0.45

Note: Figure in parentheses is square root transformed value
DAS: Days after spraying

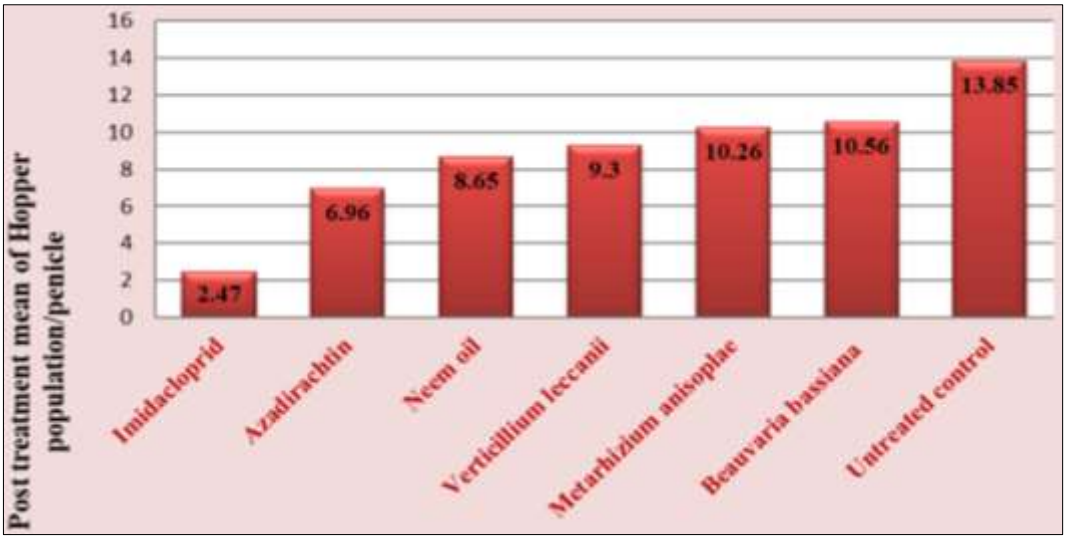

Fig 2: Bio-efficacy of biopesticides against leaf hoppers on mango after second spray at Bilaspur during 2020-21

Conclusion

Among the insecticides, the Imidacloprid was found most effective against mango leaf hoppers followed by Azadirachtin , Neem oil, *Verticillium lecanii*, *Metarhizium anisoplae* and *Beauveria bassiana*. The untreated control showed the significantly highest hoppers population and all the treatments are superior to untreated control to controlling the mango hoppers. The increasing trends of population with various treatments are as follows: Imidacloprid < Azadirachtin < Neem oil < Verticillium < Metarhizium < Beauveria.

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