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Evaluate the efficacy of biorational pesticides against the key pests of okra, *Abelmoschus esculentus* (L.) at Northern hills of Chhattisgarh

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Abstract
A field experiment was conducted at the Agriculture Research Farm of Raj Mohini Devi College of Agriculture and Research Station, Ambikapur (C.G.), during *Kharif* - 2023, to assess the efficacy of various biopesticides against key okra pests. Jassids, whitefly, aphids, and shoot and fruit borer were found to be key pests of okra plants. The results revealed that most effective treatments was Neem oil in reducing the jassids population (3.75 jassids/plant). The next most effective treatments were NSKE (3.83 jassids/plant), *B. bassiana* (4.51 jassids/plant). The treatment Neem oil was the best, treatment a recorded minimum population 3.26 whitefly/plant It was followed by treatment NSKE (3.49 whitefly/plant) and *B. bassiana* (3.71 whitefly/plant). Against aphids, NSKE was the most effective treatment, with a minimum population of 3.18 aphids per plant, followed by Neem oil (3.69 aphids per plant). Between treatments, the differences in shoot and fruit borer infestations varied from 3.68% to 12.18%. Neem oil outperformed all other spray applications in terms of infestation reduction (3.68%). The next most successful treatments were NSKE (4.31%), *B. bassiana* (5.06%), *M. anisopliae* (5.57%), *B. thuringiensis* (6.19%).

Keywords: Jassids, Whitefly, Aphids and Shoot and fruit borer, *Metarhizium anisopliae*, Neem seed kernel extract, *Bacillus thuringiensis*, *Beauveria bassiana*, Eucalyptus oil, Neeem oil

Introduction
Okra, *Abelmoschus esculentus* (L.) Moench, is a prominent vegetable crop in tropical and subtropical areas. It is commonly referred to as bhindi or lady's finger, most likely due to its characteristic elongated form, and has a high market value. It is widely cultivated in India during both the *Kharif* and summer season. Rao (1985) [12] identified Northern India as the origin of okra, while others, such as Benchasri (2012) [2] has suggested East Africa, Ethiopia, and North Egypt, although no substantial evidence supports any of these theories. Okra is well-known for its great heat and drought tolerance, and it thrives even in clay-rich soils with occasional moisture stress. However, it is susceptible to frost, which can damage the pods. Okra is a flexible crop that may be grown in both household gardens and large-scale, highly developed farms. Okra has significant nutritional, industrial, and medicinal properties. Because of their high mucilage content, the tender pods are used as vegetables as well as to thicken soups, stews, and gravies. The green tender pod includes oxalic acid, thiamine, riboflavin, and nicotinic acid, as well as vitamins A, B, and C. Calcium concentration is relatively high as compared to other vegetables, with about 66 mg per 100 g. The okra pod is known to be a high-iodine source, which is important in the treatment of throat disorders such as goiter. Okra's outstanding nutritional profile and longer shelf life have established it as a prominent export-oriented vegetable crop (Gaikwad *et al*., 2020) [4], with great potential for foreign exchange earnings. Okra accounts for almost 60% of all fresh vegetable exports (Varmudy, 2001) [4]. Furthermore, fully matured stems and fruits contain crude fibre, which is useful in the paper industry, whereas fresh roots and stems are used to purify jaggery and sugar (Chauhan and Singh. 2015) [3].

Materials and Methods

A field experiment was conducted to evaluate the efficacy of bioraional pesticides against key pests of okra during *kharif* season 2023-24. Using Deepika VNR (F1) okra variety was conducted in a randomized block design with seven treatments, viz. *Metarhizium anisopliae*, Neem seed kernel extract, *Bacillus thuringiensis*, *Beauveria bassiana*, Eucalyptus oil, and Neeem oil including an untreated control replicated three at the farm of Raj Mohini Devi College of Agriculture and Research Station, Ambikapur (C.G.). For recording counts of ten randomly selected plants, excluding the border row, were tagged, and the number of jassids, whitefly and aphids were counted on three leaves, from the upper, middle, and lower regions of the plant. Observations of sucking pests on ten selected plants from each treatment were made one day before, five, seven, and ten days later. In case of observation of Shoot and fruit borer on ten plants were randomly selected from each plot and labeled to collect shoot and fruit borer observations. As soon as the pest infestation commenced, observations on the total number of shoots, number of infested shoots (first spray), and fruit infection (second spray) of tagged plants were taken. Each tagged plant's observations were recorded one day before, five, seven, and ten days after treatment. Counting infested and uninfested shoots from each plot yielded information on shoot infestation. The extent of percent shoot infection is calculated using the formula provided by Rakshith and Kumar (2017) [11].

$$\text{Percent fruit infestation} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

Data on fruit infestation was collected by counting damaged and undamaged fruits from each plot. The percentage of fruit infestation is estimated using the following formula (Anand *et al*., 2014) [1].

$$\text{Percent fruit infestation} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruit (Healthy + Damage)}} \times 100$$

Results and Discussion

The result of efficacy of different bioraional pesticides against key pests of okra showed that all the treatments were significantly superior over control in terms of reductions of pest populations.

Field efficacy observed against Jassids (*Amrasca biguttula biguttula*)

The overall mean of 1st spray and 2nd spray of the most effective treatments was Neem oil in reducing the jassids population (3.75 jassids/plant). The next most effective treatments were NSKE (3.83 jassids/plant), *B. bassiana* (4.51 jassids/plant), *M. anisopliae* (4.73 jassids/plant), Eucalyptus oil (5.09 jassids/plant), and *B. thuringiensis* (5.40 jassids/plant). Previously, Jain *et al*. (2021) [5] published similar findings, evaluating the bio-efficacy of various biopesticides, with Neem oil and NSKE being the most effective against okra jassids. The efficacy of Neem oil and NSKE was also reported by Lal and Dhurve (2024) [8]. The efficacy of various treatments against okra jassids is presented in Table 1 & graphically depicted in Fig. 1.

Field efficacy observed against whitefly (*Bemisia tabaci)*

In the effect evaluation of the overall mean of the 1st spray and the 2nd spray, the population of whitefly recorded in various treatments ranged from 3.26 to 8.28 whitefly/plant. Compared to the other treatments, Neem oil showed higher efficacy, with a whitefly population of 3.26 whitefly/plant, which was comparable to NSKE (3.49 whitefly/plant), *B. bassiana* (3.71 whitefly/plant), *M. anisopliae* (3.94 whitefly/plant), and Eucalyptus oil (4.20 whitefly/plant) were the next highest performers. The least effective treatments were *B. thuringiensis* (4.45 whitefly/plant), but they outperformed the control (8.28 whitefly/plant). The current study is consistent with Kumar *et al*. (2021) [6], who assessed the efficacy of various bio-pesticides in reducing whitefly infestation. Neem oil and NSKE were found to be the most effective treatments in terms of control. Lal and Vishwakarma (2024) [9] found that 5% neem oil was the most effective against okra whitefly. It was followed by V. lecanii, 5% neem leaf extract, and 5% garlic clove extract. The efficacy of various treatments against whitefly is shown in Table 2 and graphically depicted in Fig. 2. The following paragraphs present the findings on the effectiveness of the various treatments.

Field efficacy observed against aphids (*Aphis gossypii)*

Overall mean of 1st spray and 2nd spray, the differences in aphid population among treatments ranged from 3.18 to 8.61 aphids/plant. Among all spray applications, NSKE was the most effective at reducing aphid populations (3.18 aphids per plant). The next most effective treatments were Neem oil (3.69 aphids/plant), *B. bassiana* (4.31 aphids/plant), *M. anisopliae* (4.55 aphids/plant), Eucalyptus oil (4.77 aphids/plant), and *B. thuringiensis* (5.04 aphids/plant). The results of Lal (2023) [7] investigation into the effectiveness of various treatments against aphids offered support for this report. NSKE, garlic clove extract, Neem oil, and *V. lecanii* were found to be the most effective treatments against the aphids population. Additionally, Gaikwad *et al.* (2020) [4] offer support for the current report. The efficacy of various treatments against aphids is presented in Table 3 and graphically depicted in Fig. 3.

Field efficacy observed against okra shoot and fruit borer (*Earias vittella)*

Overall mean of 1st spray and 2nd spray, the differences in shoot and fruit borer infestations between treatments varied from 3.68% to 12.18%. Neem oil outperformed all other spray applications in terms of infestation reduction (3.68%). The next most successful treatments were NSKE (4.31%), *B. bassiana* (5.06%), *M. anisopliae* (5.57%), *B. thuringiensis* (6.19%), and Eucalyptus oil (6.91%). Subbireddy *et al*. (2018) [13] previously published similar findings, reporting that Neem oil and Azadirachtin had the lowest larval count and fruit damage percentage, respectively, followed by NSKE and garlic bulb extract. Nana *et al*. (2022) [10] and Vongati *et al*. (2022) [15] also endorsed the current report. The efficacy of various treatments against okra shoot and fruit borer is presented in Table 4 and graphically depicted in Fig. 4.

Table 1: Efficacy of different biorational pesticides against jassids in okra

Treatments	No. of jassids/ 3 leaves/ plant 1st spray 1 DBS	5 DAS	7 DAS	10 DAS	Mean	No. of jassids/ 3 leaves/ plant 2nd spray 1 DBS	5 DAS	7 DAS	10 DAS	Mean	Overall mean of 1st and 2nd spray
T1 - *Metarhizium anisopliae*	5.30 (2.41)	4.00 (2.12)	3.87 (2.09)	4.30 (2.19)	4.06 (2.13)	8.00 (2.92)	6.10 (2.57)	5.00 (2.350	5.10 (2.37)	5.40 (2.43)	4.73 (2.29)
T2 - Neem seed kernel extract	5.15 (2.38)	3.63 (2.03)	2.40 (1.70)	3.10 (1.90)	3.05 (1.88)	7.87 (2.89)	5.50 (2.45)	4.00 (2.12)	4.37 (2.21)	4.62 (2.26)	3.83 (2.08)
T3 - *Bacillus thuringiensis*	6.27 (2.60)	5.13 (2.37)	4.10 (2.14)	5.00 (2.35)	4.74 (2.29)	8.10 (2.93)	6.00 (2.55)	5.87 (2.52)	6.30 (2.61)	6.06 (2.56)	5.40 (2.43)
T4 - *Beauveria bassiana*	5.93 (2.54)	4.67 (2.27)	3.57 (2.02)	3.47 (1.99)	3.90 (2.10)	7.33 (2.80)	5.70 (2.49)	4.67 (2.27)	5.00 (2.35)	5.12 (2.37)	4.51 (2.23)
T5 - Eucalyptus oil	6.00 (2.55)	4.93 (2.33)	3.87 (2.09)	4.40 (2.21)	4.40 (2.21)	8.23 (2.96)	6.20 (2.59)	5.20 (2.39)	5.97 (2.54)	5.79 (2.51)	5.09 (2.37)
T6 - Neem oil	6.20 (2.59)	4.13 (2.15)	2.37 (1.69)	2.50 (1.73)	3.00 (1.87)	7.50 (2.83)	5.00 (2.35)	4.07 (2.14)	4.46 (2.23)	4.51 (2.24)	3.75 (2.06)
T7 - Control	6.60 (2.66)	7.20 (2.77)	7.40 (2.81)	7.93 (2.90)	7.51 (2.83)	9.00 (3.08)	10.10 (3.26)	11.30 (3.44)	11.40 (3.45)	10.93 (3.38)	9.22 (3.11)
Sem (±)	0.10	0.12	0.11	0.13		0.13	0.14	0.13	0.15		
CD (p = 0.05)	NS	0.37	0.34	0.40		NS	0.43	0.39	0.46		
CV (%)	7.04	8.54	9.32	10.26		7.91	9.35	9.03	10.16		

Figures in parentheses are square root transformed values, DBS - Days before spray, DAS - Days after spray

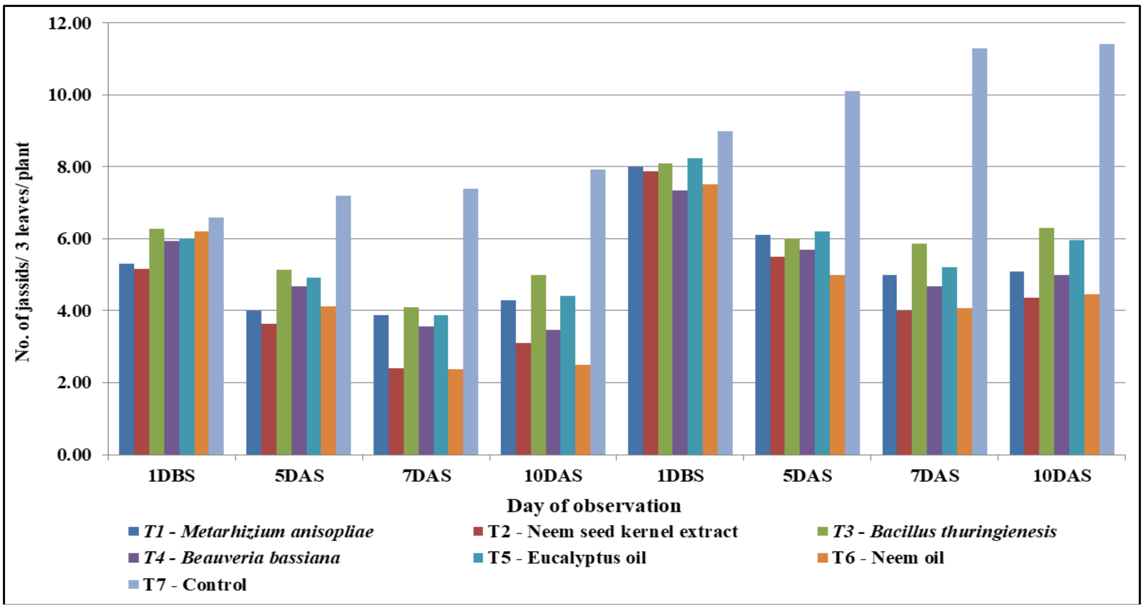

Fig 1: Effect of different biorational pesticides against jassids in okra

Table 2: Efficacy of different biorational pesticides against whitefly in okra

Treatments	No. of whitefly/3 leaves/ plant 1st spray 1 DBS	5 DAS	7 DAS	10 DAS	Mean	No. of whitefly/3 leaves/ plant 2nd spray 1 DBS	5 DAS	7 DAS	10 DAS	Mean	Overall mean of 1st and 2nd spray
T1 - *Metarhizium anisopilae*	5.30 (2.41)	3.30 (1.95)	4.10 (2.14)	4.80 (2.30)	4.07 (2.14)	6.60 (2.66)	3.90 (2.10)	3.48 (1.99)	4.03 (2.13	3.80 (2.07)	3.94 (2.11)
T2 - Neem seed kernel extract	5.13 (2.37)	3.83 (2.08)	3.13 (1.91)	3.87 (2.09)	3.61 (2.03)	6.10 (2.57)	3.67 (2.04)	2.87 (1.84)	3.57 (2.02)	3.37 (1.97)	3.49 (2.00)
T3 - *Bacillus thuringiensis*	5.50 (2.45)	4.00 (2.12)	3.93 (2.10)	5.50 (2.45)	4.48 (2.23)	5.93 (2.54)	4.13 (2.15)	4.00 (2.12)	5.13 (2.37)	4.42 (2.22)	4.45 (2.22)
T4 - *Beauveria bassiana*	5.10 (2.37)	3.20 (1.92)	3.60 (2.02)	4.33 (2.20)	3.71 (2.05)	6.93 (2.73)	3.93 (2.11)	3.27 (1.94)	3.91 (2.10)	3.70 (2.05)	3.71 (2.05)
T5 - Eucalyptus oil	5.40 (2.43)	3.90 (2.10)	3.40 (1.97)	5.17 (2.38)	4.16 (2.16)	6.23 (2.59)	4.03 (2.13)	3.74 (2.06)	4.94 (2.33)	4.24 (2.18)	4.20 (2.17)
T6 - Neem oil	4.93 (2.33)	3.67 (2.04)	2.90 (1.84)	3.67 (2.04)	3.41 (1.98)	5.97 (2.54)	3.47 (1.99)	2.64 (1.77)	3.23 (1.93)	3.11 (1.90)	3.26 (1.94)
T7 - Control	6.60 (2.66)	6.80 (2.70)	7.07 (2.75)	7.33 (2.80)	7.07 (2.75)	7.27 (2.79)	8.10 (2.93)	10.00 (3.24)	10.40 (3.30)	9.50 (3.16)	8.28 (2.96)
Sem(±)	0.13	0.11	0.11	0.12		0.12	0.11	0.12	0.12		
CD (p = 0.05)	NS	0.33	0.34	0.38		NS	0.35	0.36	0.38		
CV (%)	9.48	8.84	9.01	9.52		8.02	8.93	9.54	9.92		

Figures in parentheses are square root transformed values, DBS - Days before spray, DAS - Days after spray

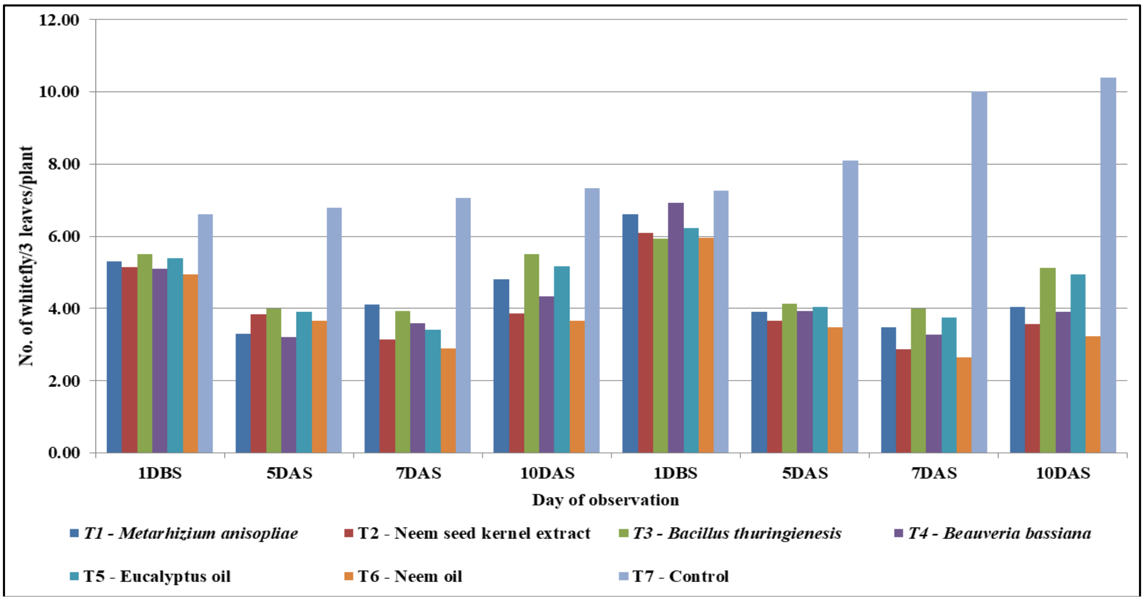

Fig 2: Effect of different biorational pesticides against whitefly in okra

Table 3: Efficacy of different biorational pesticides against aphids in okra

Treatments	No. of aphids/3 leaves/plant 1st spray				Mean	No. of aphids/3 leaves/plant 2nd spray				Mean	Overall mean of 1st and 2nd spray
	1 DBS	5 DAS	7 DAS	10 DAS		1 DBS	5 DAS	7 DAS	10 DAS		
T_1 - *Metarhizium anisoplae*	5.13 (2.37)	4.16 (2.16)	3.43 (1.98)	4.20 (2.17)	3.93 (2.10)	8.60 (3.02)	5.83 (2.52)	4.70 (2.28)	5.00 (2.35)	5.18 (2.38)	4.55 (2.25)
T_2 - Neem seed kernel extract	5.53 (2.46)	3.15 (1.91)	2.11 (1.62)	2.26 (1.66)	2.51 (1.73)	8.23 (2.95)	4.77 (2.30)	3.13 (1.91)	3.67 (2.04)	3.86 (2.09)	3.18 (1.92)
T_3 - *Bacillus thuringiensis*	4.90 (2.32)	4.32 (2.20)	3.91 (2.10)	4.47 (2.23)	4.23 (2.18)	8.10 (2.93)	6.20 (2.59)	5.33 (2.41)	6.00 (2.55)	5.84 (2.52)	5.04 (2.35)
T_4 - *Beauveria bassiana*	5.87 (2.52)	4.47 (2.23)	3.23 (1.93)	3.47 (1.99)	3.72 (2.06)	7.98 (2.91)	5.67 (2.48)	4.30 (2.19)	4.73 (2.29)	4.90 (2.32)	4.31 (2.19)
T_5 - Eucalyptus oil	5.71 (2.49)	4.57 (2.25)	3.66 (2.04)	3.94 (2.11)	4.06 (2.13)	8.95 (3.07)	6.00 (2.55)	5.10 (2.37)	5.37 (2.42)	5.49 (2.45)	4.77 (2.30)
T_6 - Neem oil	6.08 (2.57)	3.93 (2.10)	2.43 (1.71)	2.60 (1.76)	2.99 (1.87)	7.93 (2.90)	5.20 (2.39)	3.87 (2.09)	4.10 (2.14)	4.39 (2.21)	3.69 (2.04)
T_7 - Control	5.65 (2.48)	6.44 (2.63)	6.66 (2.68)	7.00 (2.74)	6.70 (2.68)	9.10 (3.10)	9.90 (3.22)	10.50 (3.32)	11.13 (3.41)	10.51 (3.32)	8.61 (3.02)
Sem(±)	0.13	0.11	0.11	0.12		0.15	0.14	0.12	0.13		
CD (p = 0.05)	NS	0.35	0.34	0.38		NS	0.43	0.38	0.40		
CV (%)	8.99	8.45	8.87	9.27		8.74	9.38	8.98	9.06		

Figures in parentheses are square root transformed values, DBS - Days before spray, DAS - Days after spray

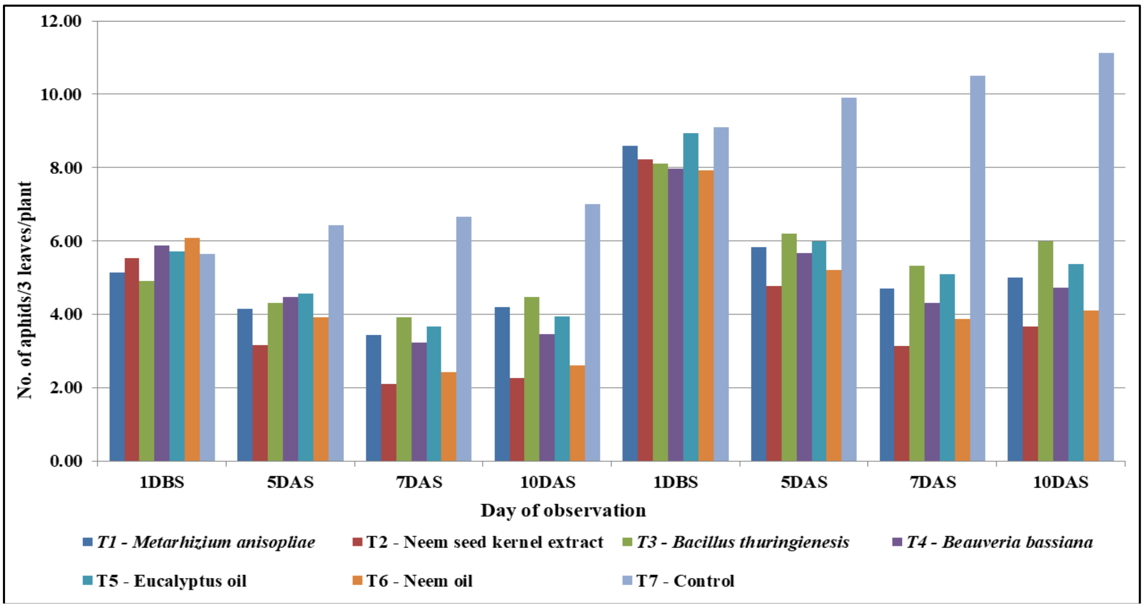

Fig 3: Effect of different biorational pesticides against aphids in okra

Table 4: Efficacy of different biorational pesticides against shoot and fruit damage caused by shoot and fruit borer in okra

Treatments	Shoot damage (%)				Mean	Fruit damage (%)				Mean	Overall mean of 1st and 2nd spray
	1st spray					2nd spray					
	1DBS	5DAS	7DAS	10DAS		1DBS	5DAS	7DAS	10DAS		
T_1 - *Metarhizium anisopliae*	7.53 (15.93)	5.13 (13.10)	3.77 (11.19)	4.27 (11.92)	4.39 (12.09)	12.10 (20.360	7.13 (15.49)	6.23 (14.46)	6.87 (15.19)	6.74 (15.05)	5.57 (13.65)
T_2 - Neem seed kernel extract	7.18 (15.54)	4.17 (11.78)	2.97 (9.92)	3.20 (10.30)	3.44 (10.70)	10.25 (18.67)	6.00 (14.18)	4.37 (12.06)	5.13 (13.10)	5.17 (13.14)	4.31 (11.98)
T_3 - *Bacillus thuringiensis*	7.87 (16.29)	5.40 (13.44)	4.00 (11.54)	4.63 (12.43)	4.68 (12.49)	11.11 (19.47)	7.93 (16.36)	7.00 (15.34)	8.20 (16.64)	7.71 (16.12)	6.19 (14.41)
T_4 - *Beauveria bassiana*	6.93 (15.26)	4.87 (12.74)	3.57 (10.89)	4.00 (11.54)	4.14 (11.75)	11.09 (19.45)	6.87 (15.19)	5.07 (13.01)	6.00 (14.18)	5.98 (14.15)	5.06 (13.00)
T_5 - Eucalyptus oil	8.13 (16.57)	6.13 (14.34)	4.60 (12.38)	5.33 (13.35)	5.36 (13.38)	12.36 (20.58)	8.10 (16.54)	8.13 (16.57)	9.13 (17.59)	8.46 (16.90)	6.91 (15.24)
T_6 - Neem oil	7.61 (16.01)	3.93 (11.44)	2.07 (8.27)	2.53 (9.16)	2.84 (9.71)	10.23 (18.65)	5.30 (13.31)	3.87 (11.34)	4.40 (12.11)	4.52 (12.28)	3.68 (11.06)
T_7 - Control	7.13 (15.49)	8.13 (16.57)	8.90 (17.36)	9.77 (18.21)	8.93 (17.39)	12.30 (20.53)	14.60 (22.46)	15.73 (23.37)	15.97 (23.55)	15.43 (23.13)	12.18 (20.43)
Sem (±)	0.73	0.63	0.74	0.84		0.87	0.88	1.01	0.97		
CD (p = 0.05)	NS	1.97	2.31	2.61		NS	2.75	3.15	3.02		
CV (%)	7.93	8.20	10.17	11.08		7.68	8.67	10.32	9.60		

Figures in parentheses are angular transformed values, DBS - Days before spray, DAS - Days after spray,

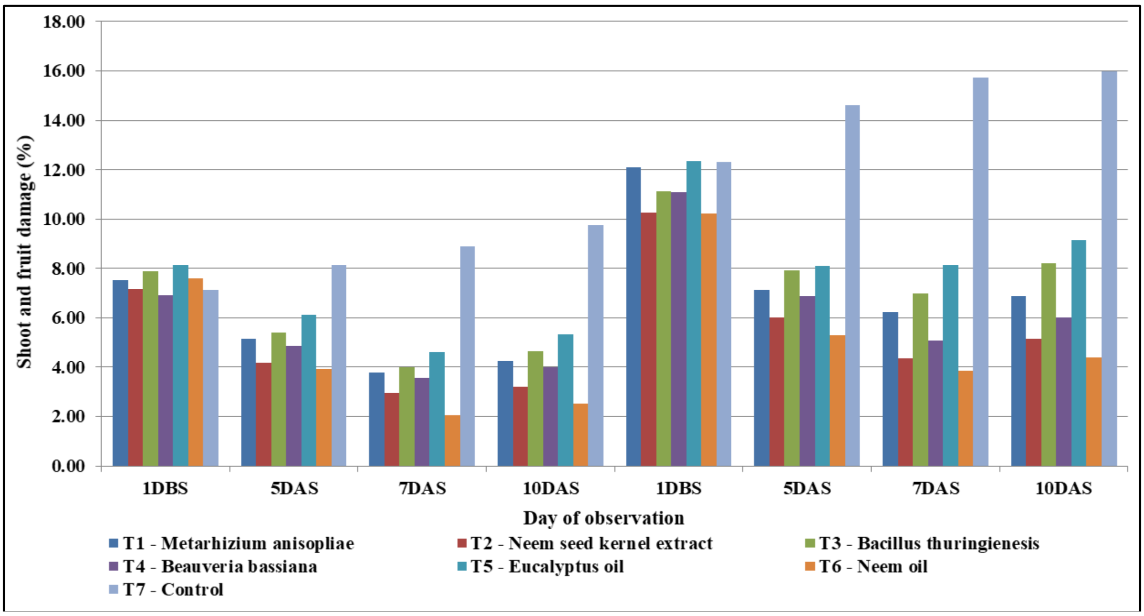

Fig 4: Effect of different biorational pesticides against shoot and fruit borer in okra

Conclusion

Among all the investigated biorational pesticides, those tested against important okra pests were shown to be significantly superior to controls, however with varying degrees of efficacy. The results revealed that the use of Neem oil resulted in the lowest population of jassids, whitefly, okra shoot and fruit borer, followed by NSKE. The most promising treatment for aphid control was NSKE, which performed equivalently to Neem oil. The next most effective treatments were *Beauveria bassiana*, *Metarhizium anisopliae*, and *Bacillus thuringiensis*.

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