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Bio-efficacy of botanical and microbial pesticides against *tetranychus urticae* koch on okra in field condition

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ABSTRACT

A study was evaluated of various botanicals against two spotted spider mite on okra crop in Bihar during summer 2022 and 2023. The combine effect of botanical and bio-pesticide against red spider mite shows best result for Azadirachtin (50.30%), followed by NSKE (46.97%), Pongamia oil 2 EC (46.41%), Eucalyptus oil (41.80%), neem oil (37.31%), Paecilomyces fumosoroseus (29.93%) stood middle of the all treatment. Lecanicilium lecanii (13.77 %) shows less per cent reduction of mite population (29.35%). The maximum yield (87.53 q/ha) was obtained in the plots treated with Azadirachtin 0.12 EC followed by NSKE (85.34 q/ha). The minimum yield of (71 q/ha) was obtained in the plots treated with Lecanicilium lecanii. The maximum Benefit Cost Ratio was also calculated in Azadirachtin (3.33:1) followed by NSKE (3.28:1) and lowest Benefit Cost Ratio was observed in Lecanicilium lecanii (2.28:1).

Keywords: *Benefit cost ratio, botanical pesticides, microbial pesticides, mites, okra.*

INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench, also known as Lady's finger, is one of the most important vegetable crops commercially cultivated in many parts of the world and in almost all the states in our country. Okra stands out as the primary green vegetable exported to numerous global regions, constituting 60% of vegetable exports, excluding onions. It is primarily used for its tender green fruits as vegetable. It is a rich source of iodine, calcium, sulfur, and sodium, alongside being a good source of vitamin A, vitamin C, thiamine, and riboflavin.[14]. The roasted and ground seeds are used as substitute for coffee powder in Turkey and seeds of bhindi also serve as a source of edible oil (oil content to the extent of 20 per cent) [8]. Okra is very useful against genito-urinary disorders and chronic dysentery [9]. Both the roots and stems of okra are used for clearing cane juice, a process utilized in the production of 'gur' or brown sugar [3]. Okra holds a vital position in the Indian horticulture, serving as an essential dietary element for individuals across various economic strata.

There are several insect and non-insect pests, which directly or indirectly inflict serious damage at different stages of vegetative growth of vegetables. According to an estimate, as many as 13 major insect and non-insect pests infest the crop at different stages in a season. Insects are widely studied but non insect - like mites are completely untouched. The mites associated with plants are both phytophagous and predatory in habit. Phytophagous mites cause serious damage to all crops including stored grain and stored products.

In recent times, the widespread presence of mites in vegetables has gained recognition as a significant constraint across the nation [2]. In Bihar, mites have caused losses to the extent from 36.8 - 83.2 per cent [6]. According to recent records in losses from 2 to 35 per cent in vegetables due to spider mites and false spider mites in Uttar Pradesh [16]. Excessive and indiscriminate use of pesticides to control these pests has resulted in undesirable ecological changes [7]. In view of the above, evaluation and adoption of different botanical and microbial pesticides for the management of spider mite on okra in a holistic manner incorporating judicious use. Hence, the present investigation was carried out to study the effectiveness of botanical and microbial pesticides against mite on okra in Samastipur district of Bihar.

MATERIALS AND METHODS

The field trial was conducted against spotted mite population on okra crop variety *'Kashi Kranti'* at vegetable growing area, Department of Horticulture, Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar. The commercial grade formulation of pesticides were tested at their recommended dose as foliar spray.

Field preparation for experiment

The okra crop requires well drained and fertile soil. The experimental plot was ploughed to make fine tilth by giving 4-5 ploughings, after which planking was done for proper leveling. FYM @ 25 t/ha was thoroughly incorporated at the time of field preparation. Okra requires 100 kg N, 60 kg P_2O_5, and 60 kg K_2O per ha as it is a long-duration a crop. Half dose of N along with full dose of P_2O_5, and K_2O was applied in the field at the time of final ploughing and thoroughly mixed.

Sowing

The sowing of seeds was done on 11 February, 2022 and 1st February, 2023.

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Irrigation
After sowing first irrigation was done followed by subsequent irrigations at 7 day interval, depending upon requirement of weather and frequency of rainfall during the experimental period.

Intercultural operation
Intercultural operations included weeding of plot at fortnightly interval the earthing-up of crop was done carefully to cover the roots of plant and hoeing operation was done twice. Weeding was done as per need.

Spraying
The eight treatments were sprayed with the help of knapsack power sprayer. The spraying was done when mites were at their peak population. During spray, cloth screen was used to avoid drifting from plot to plot. The amount of pesticides proprietary ingredient required was calculated by using the following formula-

$$A = \frac{B \times C}{D}$$

Where,
A = Amount of botanicals and microbial pesticide in grams / ml.
B = Desired concentration.
C = Amount of spray fluid required.
D = Per cent toxicants in formulation.

The proprietary ingredient so determined was mixed with 1 liter of water and sprayed on plants. The actual amount of toxicant and water required to spray was given in Table 1 and the source of supply of pesticides in Table 2.

Preparation of Neem Seed Kernel Extract (NSKE)
NSKE was prepared by collecting fresh seeds of neem from a shop selling medicinal plant products, separating the kernel from the seed coat and then thoroughly crushed the kernels with a mortar and pestle to create a fine powder. From this, 50g of the powder was soaked overnight in one liter of water. A muslin cloth was used to filter this solution and the volume was maintained for final spraying at the proper strength.

Table 1: Details of botanicals and microbial pesticide for Efficacy Study against Phytophagous Mites on okra

	Common Name	Strength of pesticides (%)	Dosage/ha
T_1	Pongamia oil	2 EC (Karanjin 20,000 PPM)	2 litre
T_2	Eucalyptus oil	0.2%	2 litre
T_3	Azadirachtin	0.15 EC (1500 PPM)	2.5 litre
T_4	NSKE	Crude form(5%)	5 litre
T_5	Neem oil	Pure (0.2%)	2 litre
T_6	*Paeciomyces fumosoroseuc*	$1x10^8$ CFUs/ml	2.5 kg
T_7	*Lecanicilium lecanii*	2×10^8 CFUs /ml	2.5 kg
T_8	Control		500 litre

Table 2: List of pesticide and source of supply for efficacy study against Phytophagous mites on okra

S.No.	Common Name	Dose/ha	Group	Source of Supply
1.	Pongamia oil	2 lit	Botanical	S.K. oil industries, Raipur
2.	Eucalyptus oil	2 lit	Botanicals	Smclassy.com, Dasprakash road, Ooty-643001
3.	Azadirachtin	5lit	Botanical	Margo Bio controls Pvt. Ltd. (Krishi-2003), Bangalore Karnataka, India.
4.	NSKE	5 lit	Botanical	Laboratory extract
5.	Neem oil	2 lit	Botanical	Self-prepared
6	*Paecilomyces fumosoroseus*	2.5 kg	Bio-Pesticides	Multiplex Bio-Tech Pvt. Ltd., 1st Main Road, Mahalakshmi Layout, Bangalore- India. 560086
7	*Lecanicilium lecanii*	2.5 kg	Bio-pesticide	Tofco, Kottayam
8	Control	500 lit		

Observations
The observations were recorded from five plants selected from each plot, tagged and numbered. Three leaves from each tagged plant were plucked from upper, middle, and lower parts and a total of three leaves were collected from each plant and 15 leaves from each plot for observations. Collected leaves were kept in polythene bags and brought to the laboratory. The mite population was counted based on 2.5 cm^2 leaf area at four spots per leaf with the help of stereoscopic binocular microscope on 1 day before (pre treatment) and after 1, 3, 7 and 14 days of spraying. The data regarding reduction in mite population in field experiment was calculated using following formula-

$$\text{Percent reduction} = \frac{\text{Average reduction in population}}{\text{Average pre-treatment population}} \times 100$$

Statistical analysis
The per cent reduction values were transformed to arcsine values before being subjected to analysis of variance to discriminate the treatment effect. The significant difference between treatments was judged by CD < 0.05% level of significance.

Yield and economics
(i) Grain Yield (kg/ha)
After ripening of pods, treatment wise harvesting, drying under sunlight and threshing of grains were done and collected plot wise in sequence to examine the bio-efficacy of varied treatments on okra yield.

There was a separate recording of yield per treatment, which was later converted to kg per hectare.

(ii) Determination of Benefit- Cost Ratio
The B:C ratio was computed by, divide the net profit after reducing the plant protection costs were calculated by subtracting the value of additional yield from the plant protection costs. The yield of different plots was recorded, and the costs of various treatments were calculated using the following formulas:
Total cost of treatment application (Rs. /ha) = Cost of insecticides + labour wages + sprayer rent.

Yield increased over control = Yield of treatment – Control
Net income (Rs. /ha) = Value of saved yield by insecticides - cost of control.

Results and Discussion
The results and discussion were undertaken for bio-efficacy of botanical and microbial pesticides against *Tetranychus urticae* Koch on okra in field condition during 2022 and 2023 at the vegetable research farm, Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar.
The efficacy of certain botanical and microbial pesticides was taken for this trail against phytophagous mite, *Tetranychus urticae* Koch on okra variety '*Kashi Kranti*' at the vegetable growing area, Department of Horticulture, Dr. Rajendra Prasad

Central Agricultural University, Pusa. The crop was treated Pongamia oil 2 EC (Karanjin 20,000 PPM), Eucalyptus oil 0.2%, Azadirachtin 0.15 EC, NSKE 5%, Neem oil 0.2%, *Paeciomyces fumosoroseus* (1x10^8 CFUs/ml), *Lecanicilium lecanii* (2 x 10^8 CFUs /ml). The data evaluate the efficacy of pretreatment, 1, 3, 7 and 14th day after treatment. The treatment also included plants sprayed with water and untreated plants in order to study the efficacy of water spray as well.

In the first spray it is evident from Table 3 and Fig. 1 the results that the increase in mite mortality is statistically significant at 5 per cent probability level in comparison to unsprayed control. Even the water spray alone reduced the mite population by 18.50 per cent maximum after first day of treatment.

On 1th DAS, NSKE was found highest mean per cent reduction of mite population (59.36%) followed by Azadirachtin 0.15 EC (59.19%), Pongamia oil 2 EC (52.45%), Eucalyptus oil (51.93%) neem oil (46.40%), *Paecilomyces fumosoroseus* (19.66), *Lecanicilium lecanii* (18.92%) among botanical and microbial pesticides respectively had significant effect when compared to water spray treatment.

On 3rd DAS, the highest mean per cent reduction (63.33%) varied significantly which was recorded in NSKE 5% followed by Azadirachtin (60.41%), Pongamia oil 2 EC (56.68%), Eucalyptus oil (55.12%), neem oil (46.40%), *Lecanicilium lecanii* (15.89%), *Paecilomyces fumosoroseus* (15.20%) among botanicals and microbial pesticide.

0n 7th DAS, the significant mean per cent reduction of mite observed highest Azadiractin (54.52%), NSKE (44.29%), Pongamia oil (46.53%), Eucalyptus oil (42.73%), *Lecanicilium lecanii* (37.43%), *Paecilomyces fumosoroseus* (36.81%), Neem oil (35.56%).

On 14th DAS where mean per cent reduction of *Lecanicilium lecanii* (45.08%) shown highest followed by *Paecilomyces fumosoroseus* (43.71%), Azadirachtin (28.27%), Pongamia oil (21.36%), Eucalyptus oil (14.54%), NSKE (11.96%), Neem oil (7.48%).

The second spray was done after 15th day of first spray and the data of the pre spray population was same as mentioned in the 14th DAS of first spray which varied significantly among all the treatment.

It is evident from Table 4 and Fig. 2 that on 1st day of the second spray, the average percentage reduction of mites showed significant variations among treatments. NSKE demonstrated the highest efficacy (61.74%), followed by Azadirachtin 0.15EC (57.61%), Pongamia oil 2 EC (54.37%), Eucalyptus oil (51.37%), and neem oil (48.07%) among botanical pesticides. Among microbial pesticides, *Paecilomyces fumosoroseus* (21.75%) and *Lecanicilium lecanii* (20.79%) also had a notable impact compared to the water spray treatment.

Significant variations were observed on the 3rd day after spraying (DAS) in the average percentage reduction of mite NSKE demonstrating the highest efficacy (64.90%), followed by Azadirachtin (60.73%), Pongamia oil 2 EC (61.35%), Eucalyptus oil (53.88%), and neem oil (53.47%) among the botanical pesticides. In the case of microbial pesticides, *Lecanicilium lecanii* (24.55%) and *Paecilomyces fumosoroseus* (25.84%) also exhibited notable effects on pest reduction compared to other treatments.

On the 7th day after spraying (DAS), there was a significant and notable average percentage reduction of mites. Azadirachtin exhibited the highest efficacy (55.80%), followed by NSKE (50.17%), Pongamia oil (55.80%), Eucalyptus oil (45.79%), Neem oil (45.20%) *Paecilomyces fumosoroseus* (33.61%), *Lecanicilium lecanii* (29.71%), among the botanical and microbial pesticides tested

On the 14th day after spraying (DAS), the recorded data has showed a contrasting trend compared to the previous results. The mean percentage reduction of *Lecanicilium lecanii* (41.67%) exhibited the highest efficacy, followed by *Paecilomyces fumosoroseus* (42.88%), Azadirachtin (24.48%), Pongamia oil (22.76%), NSKE (20.10%), Neem oil (19.60%), Eucalyptus oil (18.80%), among the tested botanical and microbial pesticides.

Table 5 demonstrate the observation on mean percent reduction of mite population. Azadirachtin (49.9%) was found effective after 1st, 3rd, 7th and 14th day after spray followed by NSKE (49.22%). Least effective treatment found was *Lecanicilium lecanii* (29.18%) which recorded better control than untreated plot.

The two spray pooled data of botanical and bio-pesticide against red spider mite shows (Table 5 and Fig. 3) best result for Azadirachtin (50.30%), followed by NSKE (46.97%), Pongamia oil 2 EC (46.41%), Eucalyptus oil (41.80%), neem oil (37.31%), *Paecilomyces fumosoroseus* (29.93 %), respectively stood middle of the all treatment. *Lecanicilium lecanii* (13.77%) shows less per cent reduction of mite population (29.35%).Based the whole performance recorded on mean percent reduction of mite on 1st, 3rd, 7th, 14th day after different applications of treatments the order of efficiency is as follows:

Azadirachtin (50.30%) > NSKE (46.97%) > Pongamia oil 2 EC (46.41%) > Eucalyptus oil (41.8%) > neem oil (37.31%) > *Paecilomyces fumosoroseus* (29.93%) > *Lecanicilium lecanii* (29.35%).

After two sprays, the yield of okra fruits was calculated, and the results showed that the maximum output (87.53 q/ha) was significantly higher than the control plot when the fruit was harvested from the plots treated with azadirachtin and then NSKE stood second highest with a yield of (85.34q/ha) after that pongamia oil in which the yield was recorded (83.56 q/h). In eucalyptus oil yield was recorded (82.79 q/ha) which is higher than neem oil. In *Paecilomyces fumosoroseus* the yield was recorded (71.76q/ha) which was higher than *Lecanicilium lecanii* (71.00 q/ha) in which the yield was recorded lowest in all the treatment the yield was higher than control which is 60.34 q/ha (table 6).

The benefit – cost ratio was significantly influenced by different botanical and microbial pesticides on okra (Table 6). Among the treatments, values ranged from (3.33:1) to (2.36:1). The maximum benefit-cost ratio was recorded with Azadirachtin treated okra plots at (3.33:1) followed by NSKE treated plots at (3.28:1). The lowest cost-benefit ratio was observed in *Lecanicilium lecanii* treated plot at (2.68: 1).

In the present finding Azadirachtin 0.15 EC have shown most effective results in comparison to other eco-friendly treatments. These findings show close conformity with previous published work like [11], [12] and [17] found Azadirachtin 0.15 EC against the red spider mite, *Tetranychus urticae* Koch on okra. The effectiveness of Azadirachtin (1%) against *T. urticae* resulted in population reductions of 70.16% and 70.95% in the first and second seasons, respectively [5]. The initial application, the initial population of the red spider mite *Tetranychus urticae* in plots [18]. Studies by worker observed that the percent reduction of mite is highest in pongamia oil which is higher than neem oil [15]. Workers was founded that Azadirachtin 1% shows higher percentage reduction of mite population in okra crop [1].

Azadirachtin 0.15 EC performed exceptionally well in managing mite populations and enhancing fruit yield under both management approaches [19]. Some workers observed effectiveness of various botanicals against the sucking pests of brinjal, specifically the red spider mite (*Tetranychus urticae* Koch) in which [4] and [12]. The evaluation of aqueous extracts revealed that the commercial formulation Azadirachtin 0.003 EC demonstrated efficacy against mite population followed by Neem Seed Kernel Extract (NSKE) at a concentration of 5% exhibited significant effectiveness. Studies by found that pongamia oil shows higher mite percentage reduction than neem oil [13]. Among the plant-based oils, karanj oil was most effective against red spider mites [10].

Table 3: Effectiveness of botanical and microbial pesticides against Tetranychus urticae Koch on okra in field condition (First spray)

Treatments	Mean Pre-spraying population /2.5 cm² leaf area	Mean per cent reduction in mite population day after spraying				Mean
		1 DAS	3 DAS	7 DAS	14 DAS	
T_1- Pongamia oil	24.57	52.45 (46.41)	56.68 (48.84)	46.53 (43.01)	21.36 (27.53)	44.26 (41.70)
T_2-Eucalyptus oil	26.17	51.93 (46.11)	55.12 (47.94)	42.73 (40.82)	14.54 (22.42)	41.08 (39.86)
T_3-Azadirachtin	23.33	57.19 (49.14)	60.41 (51.01)	54.52 (47.60)	28.27 (20.24)	50.10 (41.98)
T_4-NSKE	21.10	59.36 (50.39)	63.33 (52.73)	44.29 (41.72)	11.96 (20.24)	44.73 (41.98)
T_5Neem oil	24.47	43.74 (41.41)	46.40 (42.94)	35.56 (36.61)	7.48 (15.88)	33.30 (35.24)
T_6-*Paecilomyces fumosoroseus*	23.43	18.92 (25.78)	15.89 (23.49)	37.43 (37.72)	45.87 (42.63)	29.52 (32.92)
T_7-*Lecanicilium lecanii*	23.20	19.66 (26.32)	15.20 (22.95)	36.81 (37.35)	43.71 (41.39)	28.84 (32.48)
T_8-Control (Water Spray)	24.67	18.50 (25.48)	14.05 (22.02)	9.76 (18.20)	4.0 (11.62)	11.59 (19.91)
S.E m±		1.86	1.90	1.81	1.37	1.73
CD at 5%	NS	5.69	5.83	5.56	4.23	5.32
CV		8.30	8.56	8.38	9.24	8.62

**Mean of 5 plants per plot, 3 leaves of leach plant and one leaf 2.5 cm2 areas of four spot. DAS-Day after spray, Figures in parenthesis are Arcsine transformed value*

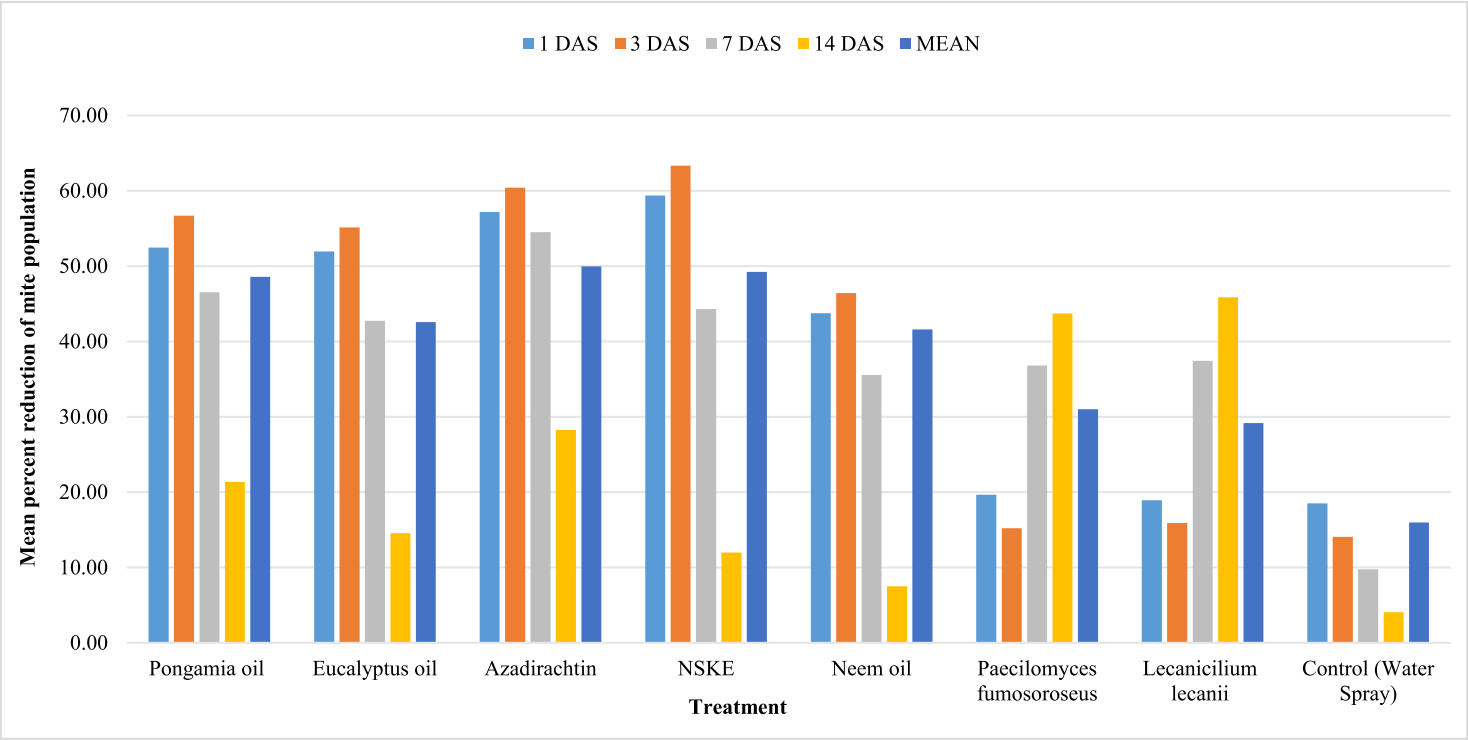

Fig 1: Bio-efficacy of botanicals and microbial pesticides against T. urticae on okra after first spray

Table 4: Effectiveness of botanical and microbial pesticides against Tetranychus urticae Koch on okra in field condition (2nd spray)

Treatments	*Mean Pre-spraying population/ 2.5 cm² leaf area	Mean percent reduction in mite population day after spraying				Mean
		1 DAS	3 DAS	7 DAS	14 DAS	
T_1- Pongamia oil	19.21	54.37 (47.51)	61.35 (51.56)	55.80 (48.33)	22.76 (28.49)	48.57 (44.18)
T_2-Eucalyptus oil	22.37	51.81 (46.04)	53.88 (47.23)	45.79 (42.58)	18.80 (25.70)	42.57 (40.73)
T_3-Azadirachtin	16.61	57.61 (49.38)	60.73 (51.20)	57.02 (49.04)	24.48 (29.65)	49.96 (44.98)
T_4-NSKE	18.57	61.74 (51.79)	64.90 (53.67)	50.16 (45.09)	20.10 (26.64)	49.22 (44.55)
T_5Neem oil	22.53	48.07 (43.89)	53.47 (46.99)	45.20 (42.25)	19.60 (26.28)	41.59 (40.16)
T_6 *Paecilomyces Fumosoroseus*	13.33	21.75 (27.80)	25.84 (30.55)	33.61 (35.43)	42.88 (40.91)	31.02 (33.85)
T_7 *Lecanicilium lecanii*	12.23	20.79 (27.13)	24.55 (29.70)	29.71 (33.03)	41.67 (40.20)	29.18 (32.70)
T_8 Control (Water Spray)	23.57	22.95 (28.62)	20.66 (27.03)	14.66 (22.51)	5.58 (13.66)	15.96 (23.55)
S.E m±	1.37	1.38	1.29	1.41	1.38	1.36
CD at 5%	4.23	3.98	3.92	4.30	4.10	4.07
C.V.	9.24	9.12	9.88	10.34	9.56	9.72

Figures in parenthesis are Arcsine transformed value

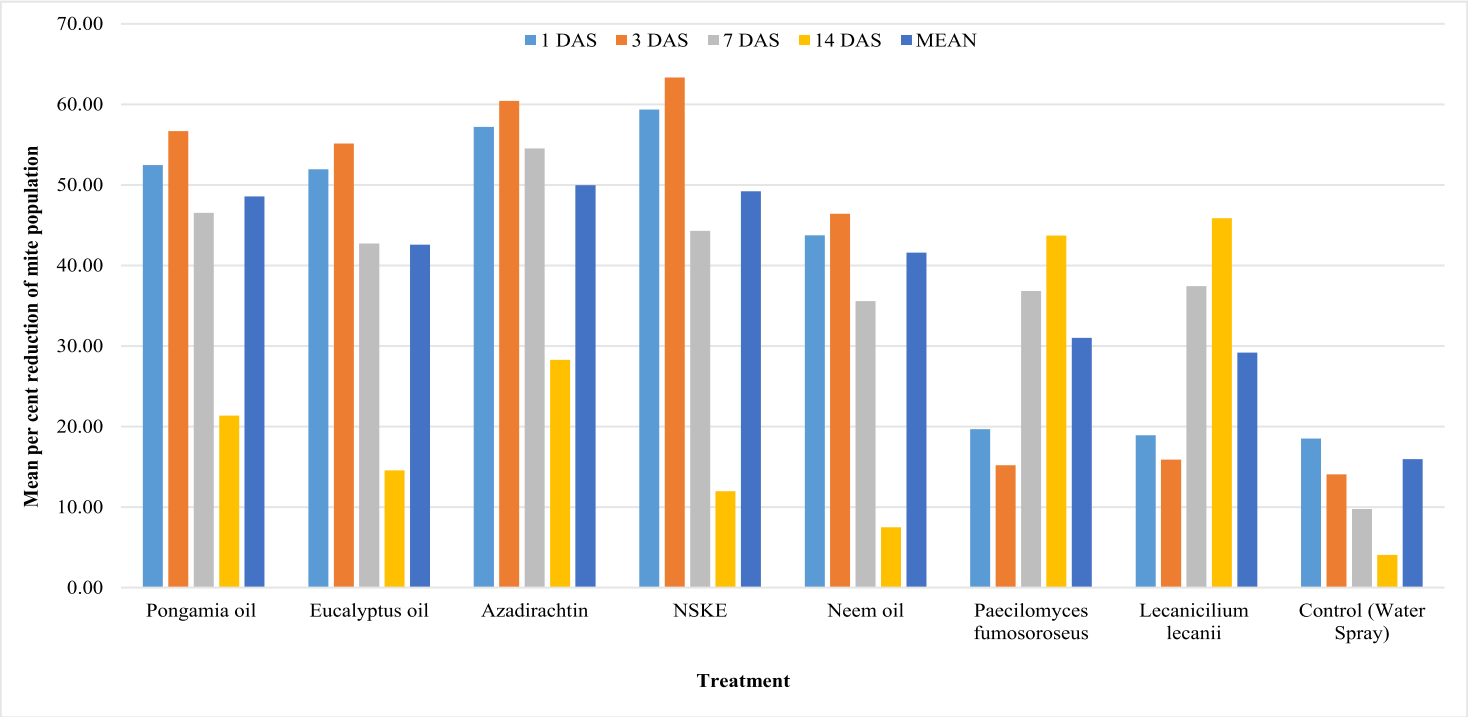

Fig. 2: Bio-efficacy of botanicals and microbial pesticides against T. urticae on okra after second spray

Table 5: Effect of botanicals and microbial pesticide against mite, T. urticae on okra after two sprays

Treatments	Mean per cent reduction in mite population day after spraying		
	1st spray	2nd spray	Pooled mean
T_1 - Pongamia oil 2 EC	44.26 (41.70)	48.57 (44.18)	46.41 (42.9)
T_2 -Eucalyptus oil	41.08 (39.86)	42.57 (40.73)	41.80 (40.28)
T_3 -Azadirachtin 0.15 EC	50.10 (41.98)	49.96 (44.98)	50.30 (45.17)
T_4 -NSKE	44.73 (41.98)	49.22 (44.55)	46.97 (43.2)
T_5 Neem oil	33.30 (35.24)	41.59 (40.16)	37.31 (37.64)
T_6 -*Paecilomyces fumosoroseus*	28.84 (32.48)	31.02 (33.85)	29.93 (33.16)
T_7 -*Lecanicilium lecanii*	29.52 (32.92)	29.18 (32.70)	29.35 (32.80)
T_8 -Control (ater Spray)	11.59 (19.91)	15.96 (23.55)	13.77 (21.7)
S.E m±	1.73	1.36	
CD at 5%	5.32	4.07	
CV	8.62	9.72	

Figures in parenthesis are Arcsine transformed value

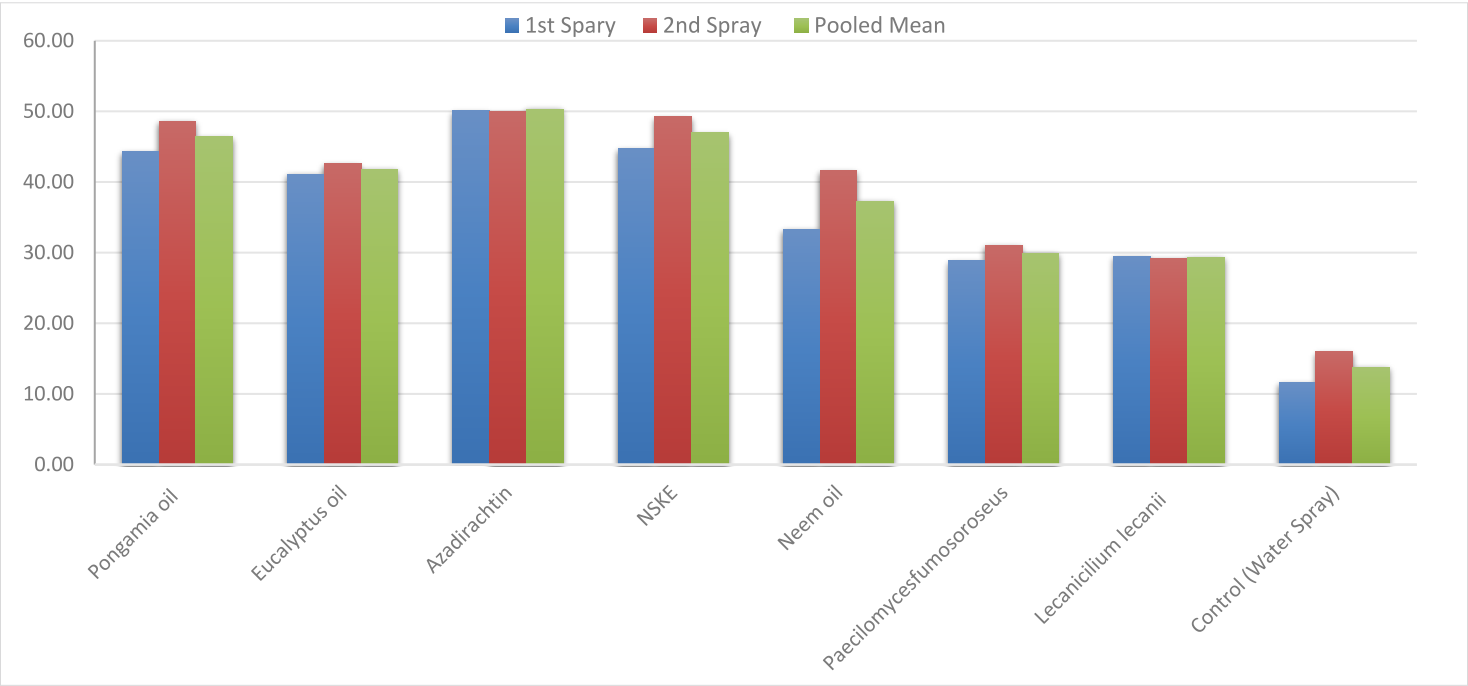

Fig. 3: Bio-efficacy of botanicals and microbial pesticides against T. urticae on okra after two spray

Table 6: Yield and economics of different botanicals and microbial pesticides applied against two spotted spider mite on okra

Treatment	Yield (q/ha)	Yield increase over control (t/ ha)	% increase over control	Insecticides +Labour (spraying)	Total cost	Gross return	Net return	B:C Ratio
T_1 - Pongamia oil 2 EC	83.56	23.22	38.48	2936	60936	192188	131252	3.15:1
T_2 -Eucalyptus oil	82.79	22.45	37.21	6936	64936	190417	125481	2.93:1
T_3 -Azadirachtin 0.15 EC	87.53	27.19	45.06	2511	60511	201319	140808	3.33:1
T_4 -NSKE	85.34	25	41.43	1886	59886	196282	136396	3.28:1
T_5 Neem oil	78.35	18.01	29.85	3036	61036	180205	119169	2.95:1
T_6 -*Paecilomyces fumosoroseus*	71.76	11.42	18.93	3211	61211	165048	103837	2.70:1
T_7 -*Lecanicilium lecanii*	71.00	10.66	17.67	2861	60861	163300	102439	2.68:1
T_8 -Control (water spray)	60.34			818	58818	138782	79964	2.36:1

**Mean of three replications Common cost – Rs. 58000/-*
Number of sprays: 3 Labour charge: 409/day/person
No. of labours required: 2 persons/spray/hectare Price of marketable Okra: @ Rs 2300/q

CONCLUSION

The results of this study aims to raise awareness among native farmers about how to manage them to mitigate yield reduction issues. The approach involves utilizing effective acaricides that ensure crop safety and are also beneficial for human health. To reach a reliable conclusion, it is essential to conduct further investigations on pest problems in various regions and seasons. These investigations should involve the implementation of different improved management practices aimed at maintaining pest populations below the Economic threshold level (ETL). This approach will ultimately lead to higher returns from okra cultivation.

CONFLICT OF INTEREST: Authors declare no conflict of interest related to this work.

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