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Efficacy and Economics of Plant Extract and Chemicals Insecticide, against Mustard Aphid, *Lipaphis erysimi* (Kalt)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment conducted at the Student Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture & Technology Kanpur during the *Rabi* season of 2021-2022. The experiment focused on the Indian mustard variety *Varuna* and included eight treatments, including a control plot. Among the treatments, it was observed that the population of aphids on the top 10 cm apical twigs ranged from 1.23 to 25.56 aphids per plant. The treatment with Thiamethoxam 25 WG @ of 0.2g/liter showed a significantly lower aphid population, with only 1.23 aphids on the top 10 cm

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central twig per plant compared to the control. Additionally, this treatment resulted in the maximum yield of 18.73q/ha, which was superior to the other treatments. Furthermore, the treatment with Thiamethoxam 25 WG at a rate of 0.2g/liter also showed the highest net income gain of Rs. 54414/ha. The cost-benefit ratio analysis indicated that this treatment ranked first, with a B: C ratio of 1:40.63, suggesting the highest returns on investment. These findings suggest that the application of Thiamethoxam 25 WG at a rate of 0.2g/liter can effectively control aphid populations and enhance the yield and profitability of Indian mustard cultivation.

Keywords: Mustard aphid; chemical Insecticides; botanicals and management.

1. INTRODUCTION

Mustard, scientifically known as *Brassica juncea* (L) Primarily grown for its seeds, this significant oilseed crop is utilized in the production of mustard oil and serves as a flavoring agent. Mustard is a member of the Brassicaceae family, which includes other economically significant crops such as cabbage, broccoli, and cauliflower. Mustard is cultivated on 6.23 million hectares in India, with a production reaching 9.34 million tonnes and a productivity rate of 1499 kg/hectares [1]. Canada has high hopes for a plentiful harvest of 16.90 million tons of mustard seeds in 2021, which is a slight decrease from the 18.6 million tonnes produced in 2020. This anticipated drop in production could affect the global mustard seed market. Fascinating, isn't it? Let's continue to monitor the global progress in the mustard industry [2-4]. An anonymous report from 2022 predicts a 4% increase in worldwide mustard seed production for the 2021-2022 periods, totaling 741 lakh tonnes [5-9]. This growth suggests a positive trend in mustard seed production on a global scale. However, without further context or details, such as regional production changes or factors influencing this increase, it's challenging to provide a more in-depth analysis. Additionally, it's worth noting that since this information is from an anonymous source, it may be beneficial to cross-reference with official sources or reports for validation [10-13].

The states of Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, and Assam collectively accounted for a significant portion of India's rapeseed-mustard growing area and production, as stated in your report. Specifically, these states contributed to approximately 86.29% of the country's rapeseed-mustard growing area and 88.46% of its production. Within Uttar Pradesh, several districts played a prominent role in rapeseed-mustard cultivation. These districts include Kanpur, Kanpur Dehat, Gonda, Saharanpur, Meerut, Faizabad, Etawah, Bulandshahar, Mathura, Aligarh, and others. These regions are known for their conductive agro-climatic conditions, which are suitable for rapeseed-mustard cultivation. Rapeseed-mustard cultivation in these states is vital for India's agriculture and economy, contributing significantly to both food and oilseed production [14-16]. Additionally, it provides livelihood opportunities for farmers and supports various ancillary industries related to oilseed processing and distribution and 38 insect pests are known to be connected with the rapeseed-mustard crop in India. The most devastating insect pest is the mustard aphid. *Lipaphis erysimi* Kalt. It not only lowers seed yields by up to 73.3 per cent, but it also lowers oil content by up to 66.9%.

Mustard aphid generally emerges in late December and remains active until the conclusion of March, thoroughly feasting on the plant's cell sap. This pesky insect, presenting as both nymphs and grown-ups, indulges in a buffet across various plant regions like flowers, leaves, stems, twigs, and even pods! Dwelling in colonies with a reproduction rate that's out of this world [17-20]. Aphids start their journey on vegetative buds, swiftly expanding their territory throughout the plant, leading to its eventual weakening and deterioration. in severe infestations, plants simply give up and refuse to produce any pods, coming to a sad, stunted end.

Honeydew is a sweet, sticky substance excreted by aphids and some other sap-sucking insects as they feed on plant sap. When aphids consume large amounts of sap, they excrete honeydew in significant quantities. This honeydew often accumulates on leaves and other surfaces of plants [21-23]. Sooty mold, also known as sooty mold fungus, can grow on the honeydew excreted by aphids. This mold forms a dark, velvety coating on the surfaces of leaves and stems. While sooty mold itself doesn't directly harm the plant, it can indirectly affect the plant's health by obstructing photosynthesis. Low temperatures of 8-18°C, along with 60-80%

relative humidity, gloomy, and light rainy weather conditions, are ideal for insect reproduction. The mustard aphid alone causes about 9 to 96 per cent losses [24] per cent in oil content. The occurrence of this insect is very much influenced by environmental factors and *Brassica spp*. grown. Farmers and agricultural professionals must monitor aphid populations regularly and implement appropriate control measures to prevent extensive damage caused by these pests. By understanding the relationship between aphids, honeydew, and Sooty Mold, proactive steps can be taken to protect plant health and ensure optimal crop production.

2. MATERIALS AND METHODS

The field test mentioned took place at the Student Instructional Farm (SIF) of Chandra Shekhar Azad University of Agriculture & Technology in Kanpur, Uttar Pradesh, India. This occurred during the Rabi season of 2021-2022, focusing on the Indian Mustard variety *Varuna* Eight different treatments, one control plot, evaluated using a randomized block setup with three replications. Two rounds of spraying were carried out at fifteen-day intervals. The initial application occurred 78 days after seeding, followed by a second spray 90 days later. The experiment involved the application of different chemical insecticides and plant extracts. These included NSKE (*Neem* Seed Kernel Extract) at a concentration of 5%, *Neem* leaf extract at 5%, *Neem* oil at 2%, Eucalyptus leaf extract at 5%, and fennel leaf extract at 5%. Additionally, two chemical insecticides were used like Dimethoate (30 EC) at a concentration of 1 ml/l and Thiamethoxam (25 WG) at a concentration of 0.2 gm/lit. The application was done using a manually operated knapsack sprayer equipped with a Duro mist nozzle. The number of aphids present on a 10 cm apical central twig of each plant was recorded. This data was collected one day before the spraying process and at specific intervals after spraying: 3, 7, 10, and 15 days. Evaluation Period: The efficacy of various treatments was evaluated over a period of 15 days following the application.

2.1 Determination of the Amount of Insecticides

However, typically, the formula for calculating the quantity of pesticide required for a given area (in hectares) involves the following steps:

i. Determine the recommended application rate of the pesticide per hectare. This information is usually provided on the pesticide label or in the recommendations from agricultural authorities.
ii. Calculate the total area to be treated in hectares.

Multiply the application rate (in liters or grams per hectare) by the total area to be treated to obtain the total quantity of pesticide needed.

The required amount of insecticide = (Volume of water (lit.)× Desired concentration (%) / % Strength of insecticide formulation)

Economics of treatment:

Pest infestation (%) = (No.of infested plant / Total no of randomly selected plants) ×100

Pest intensity = (otal no of nymph and adult found on plant to observed / No of plant observed)

The mean original data of observations was calculated as per cent reduction over control with following formula **Abbot's formula 1925**.

$$A = \frac{C - T}{C}$$

Where,

A= reduction percent in population over control.
C= percent damage of control.
T= percent damage of treated plot.

The mustard seed weight from each plot was individually assessed. The collected data underwent statistical analysis. The Incremental Cost-Benefit Ratio (ICBR) for each treatment can be determined by dividing the net profit yielded by that treatment by the total cost of the associated plant protection measures. Here's the formula:

Incremental Cost: Benefit Ratio (ICBR)= (Net Income / Management cost)

3. RESULTS AND DISCUSSION

The field test was conducted to assess the effectiveness of chemical pesticides and plant extracts in controlling mustard aphids during the *rabi* crop season. Eight different treatments were evaluated, including NSKE at 5%, *Neem* Leaf Extract at 5%, *Neem* Oil at 2%, Eucalyptus Leaf

Extract at 5%, Fennel Seed Extract at 5%, Dimethoate 30 EC at 1.0 ml/lit, Thiamethoxam 25 WG at 0.2 g/lit, and an untreated plot. The population of mustard aphids was monitored continuously until it reached the economic threshold level (20 aphids on the top 10 cm central twig per plant). The initial observations of the aphid population were recorded one day before the application of treatments. Subsequent observations were made on three, seven, ten, and fifteen days after the treatments were sprayed. This interval allowed for monitoring the effectiveness of the treatments over time and assessing any changes in the aphid population following the application of the treatments.

3.1 Impact of Treatment on the Population of Mustard Aphids Following the First Spray

During the initial observation, the average number of mustard aphids on the upper 10 cm of the central plant twig ranged from 48.50 to 63.07. All treatments effectively reduced the aphid population compared to the untreated group. Mustard aphids declined with treatments like plant extracts and chemical insecticides, while they increased in the control plot." - should be "Mustard aphids declined with treatments like plant extracts and chemical insecticides, while it's increased in the control plot.

Three days post-treatment, variations were significant among the treatments. Notably, The concentration of Thiamethoxam 25 WG is 0.2 grams per liter showed the lowest aphid count (9.66 aphids) on the top 10cm of the central twig/plant, distinguishing it from the other treatments. The concentration of Thiamethoxam 25 WG is 0.2 grams per liter emerged as the most potent insecticide, followed by Dimethoate 30 EC @ 1.0 ml/lit with 12.76 aphids. Among plant extracts, NSKE @ 5% exhibited the least aphid population of 25.43 aphids, proving its effectiveness in controlling mustard aphids compared to other extracts after three days of application." - should be "among plant extracts, NSKE @ 5% exhibited the least aphid population of 25.43 aphids, proving its effectiveness in controlling mustard aphids compared to other extracts after three days of application.

This finding indicates at 7 days that all the treatments, including the various chemical insecticides and plant extracts, had a positive impact on controlling the aphid population when compared to the untreated control group. The application of Thiamethoxam 25 WG at a concentration of 0.2 g/lit led to the smallest average population of mustard aphids, with an average count of 5.50 aphids on each 10 cm section of the central twig of a plant. Following this, the use of Dimethoate 30 EC at a concentration of 1.0 ml/lit resulted in the next smallest average population of mustard aphids, with an average count of 8.43 aphids on each 10 cm section of the central twig of a plant. These two treatments (Thiamethoxam and Dimethoate) showed significantly lower aphid populations compared to the rest of the treatments, among five plant extracts: NSKE at a concentration of 5%, *Neem* oil at 2%, *Neem* Leaf Extract at 5%, Eucalyptus Leaf Extract at 5%, and Fennel Seed Extract at 5%. The aphid populations observed in these treatments varied between 20.60 and 45.36. Notably, *Neem* Leaf Extract at 5% and *Neem* Oil at 2% demonstrated similar effectiveness, with comparable aphid populations noted 7 days post the initial spray.

The populations of mustard aphids were observed ten days after the initial spray, revealing that two treatments were found to be at par in terms of their effectiveness in controlling the pest. These treatments were Thiamethoxam 25 WG at a concentration of 0.2 g/lit and Dimethoate 30 EC at a concentration of 1.0 ml/lit both Thiamethoxam and Dimethoate treatments resulted in similar mean populations of mustard aphids, with 6.73 and 4.36 aphids per 10 cm of central twig per plant, respectively. This indicates that these treatments continued to demonstrate effective control of the aphid population even ten days after the initial application. Among plant extract, NSKE (*Neem* Seed Kernel Extract) @ 5% was found to be very effective in controlling mustard aphids, with a mean population of 18.33 aphids on the top 10 cm central twig per plant. This indicates that NSKE at 5% was successful in significantly reducing the aphid population compared to untreated plants. Eucalyptus Leaf Extract @ 5% also demonstrated effectiveness against mustard aphids, with a mean population of 42.56 aphids on the top 10 cm central twig per plant. It produced significantly different results compared to *Neem* Oil @ 2% and Fennel Seed Extract @ 5%, which were found to be at par with *Neem* Leaf Extract @ 5% (with mean populations of 26.66, 30.20, and 30.76 aphids, respectively, on the top 10 cm central twig per plant). These findings suggest that NSKE at 5% and Eucalyptus Leaf Extract @ 5% were effective treatments for controlling mustard aphids. Additionally, *Neem* Oil @ 2%, Fennel Seed Extract @ 5%, and *Neem* Leaf Extract @

5% showed similar efficacy, with their effectiveness being comparable to each other.

The mustard aphid population was observed at 15 days following the beginning spray, and it was found that there were notable differences between the treatments. Thiamethoxam 25 WG at a concentration of 0.2 g/lit resulted in the significantly lowest population of mustard aphids, with an average of 3.73 aphids on the top 10 cm central twig per plant. Thiamethoxam was identified as the most effective insecticide among those tested. Dimethoate 30 EC @ 1.0 ml/lit the second-highest population of mustard aphids, with an average of 5.40 aphids on the top 10 cm central twigs per plant. NSKE @ 5% and *Neem* Oil @ 2% these two treatments were found to be at par with the other five plant extracts, with mean populations of 4.11 and 4.78 aphids on the top 10 cm central twig per plant, respectively. *Neem* Leaf Extract 5% mean population of 26.56 aphids on the top 10 cm central twig per plant, which was found to be at par with 5% Eucalyptus Leaf Extract and 5% Fennel Seed Extract. These plant extracts had mean populations of 33.13 and 35.40 aphids per plant, respectively. These findings provide valuable insights into the effectiveness of different insecticides and plant extracts in managing mustard aphid populations. Thiamethoxam was identified as the most effective insecticide, while various plant extracts showed comparable efficacy in controlling aphids.

3.2 Impact of Treatment on the Population of Mustard Aphids Following the Second Spray

The population of mustard aphids, assessed a day before the spraying process, showed significant variations across different treatments. The treatment with The concentration of Thiamethoxam 25 WG is 0.2 grams per liter resulted in the smallest aphid population, On average, there are 11.80 aphids on each 10 cm section of the central twig of a plant, marking it as the most potent insecticide against mustard aphids. The NSKE treatment, with a population of 18.76 aphids on each 10 cm section of the central twig of a plant was found to be equally effective as Thiamethoxam. The *Neem* Oil treatment, comparable to the *Neem* Leaf Extract @ 5%, resulted in populations of 28.50 and 38.60 aphids on each 10 cm section of the central twig of a plant, respectively. After the first spray, this treatment led to a population of 43.40 aphids on each 10 cm section of the central twig of a plant. These observations offer valuable insights into the efficacy of various treatments in controlling mustard aphid populations. Thiamethoxam, NSKE, *Neem* Oil, and *Neem* Leaf Extract demonstrated promising outcomes in reducing aphid populations, whereas the Eucalyptus Leaf Extract led to an increase in aphid populations post the initial spray.

Observations were made three days post the second spray. Both Thiamethoxam 25 WG @ 0.2 g/lit and Dimethoate 30 EC @ 1.0 ml/lit proved highly potent against mustard aphids, yielding populations of 9.96 and 10.70 aphids on each 10 cm section of the central twig of a plant, respectively. They also achieved substantial control percentages of 94.26% and 93.06%, respectively. NSKE @ 5% resulted in a population of 16.36 aphids on each 10 cm section of the central twig of a plant, with a control percentage of 90.22%. *Neem* Oil @ 2% and *Neem* Leaf Extract @ 5% were equally effective against mustard aphids, yielding populations of 23.20 and 24.63 aphids on each 10 cm section of the central twig of a plant, respectively. They achieved control percentages of 86.14% and 85.28% over the control, respectively. Eucalyptus Leaf Extract @ 5% and Fennel Seed Extract @ 5% were also equally effective against mustard aphids, yielding populations of 32.50 and 34.50 aphids on each 10 cm section of the central twig of a plant, respectively. They achieved control percentages of 80.58% and 79.39% over the control, respectively. These findings underscore the potency of Thiamethoxam and Dimethoate as the most effective insecticides against mustard aphids, followed by NSKE, *Neem* Oil, *Neem* Leaf Extract, Eucalyptus Leaf Extract, and Fennel Seed Extract.

Seven days following the second spray, observations revealed that both Thiamethoxam 25 WG @ 0.2 g/lit and Dimethoate 30 EC @ 1.0 ml/lit were equally effective treatments against mustard aphids, yielding populations of 4.86 and 6.33 aphids on each 10 cm section of the central twig of a plant, respectively. NSKE @ 5% resulted in a population of 16.36 aphids on each 10 cm section of the central twig of a plant. Similarly, Eucalyptus Leaf Extract @ 5% and Fennel Seed Extract @ 5% were equally effective against mustard aphids, yielding populations of 30.63 and 32.53 aphids on each 10 cm section of the central twig of a plant, respectively. These findings suggest that Thiamethoxam, Dimethoate, NSKE, Eucalyptus

Table 1. Impact of treatment on the population of mustard aphids, *Lipaphis erysimi* (Kalt.) after first spray

T. No.	Treatment	Mean population of mustard aphid top10 cm central twig / plant								
		Dose	Before Spray	3DAS	PROC	7DAS	PROC	10DAS	PROC	15DAS	PROC
1	NSKE	5%	55.30 (7.46)	25.43 (5.09)	78.54	20.60 (4.59)	85.63	18.33 (4.33)	87.65	16.43 (4.11)	88.97
2	*Neem* leaf extract	5%	63.07 (7.97)	36.96 (6.12)	68.52	32.03 (5.70)	77.66	30.76 (5.59)	79.28	26.56 (5.20)	82.69
3	*Neem* oil	2%	61.66 (7.88)	33.36 (5.81)	71.59	29.60 (7.48)	79.35	26.66 (5.21)	82.04	22.43 (4.78)	85.38
4	Eucalyptus leaf extract	5%	60.76 (7.82)	48.72 (7.01)	58.51	41.56 (6.48)	71.01	42.56 (6.56)	71.33	33.13 (5.79)	78.41
5	Fennel seed extract	5%	58.86 (7.68)	49.05 (7.03)	58.23	45.36 (6.77)	68.36	30.20 (5.54)	79.66	35.43 (5.99)	76.91
6	Dimethoate 30 EC	1ml/lit	50.60 (7.14)	12.76 (3.64)	89.10	8.43 (2.98)	94.12	6.73 (2.68)	95.73	5.40 (2.42)	96.48
7	Thiamethoxam 25 WG	0.2 g/lit	52.43 (7.27)	9.66 (3.18)	91.77	5.50 (2.44)	96.16	4.36 (2.20)	97.06	3.73 (2.05)	97.56
8	Control		48.50 (7.00)	117.66 (10.87)		143.40 (11.99)		148.48 (12.20)		153.49 (12.40)	
SE(m) ±				0.270		0.196		0.201		0.211	
C.D at 5%			N.S.	0.827		0.601		0.615		0.646	

DOS (Date of spraying) 08-02-2022
DBS (Day before spray)
DAS (days after spray)
PROC (Per cent over control)
Figure within parentheses is square root (√ X+.5)

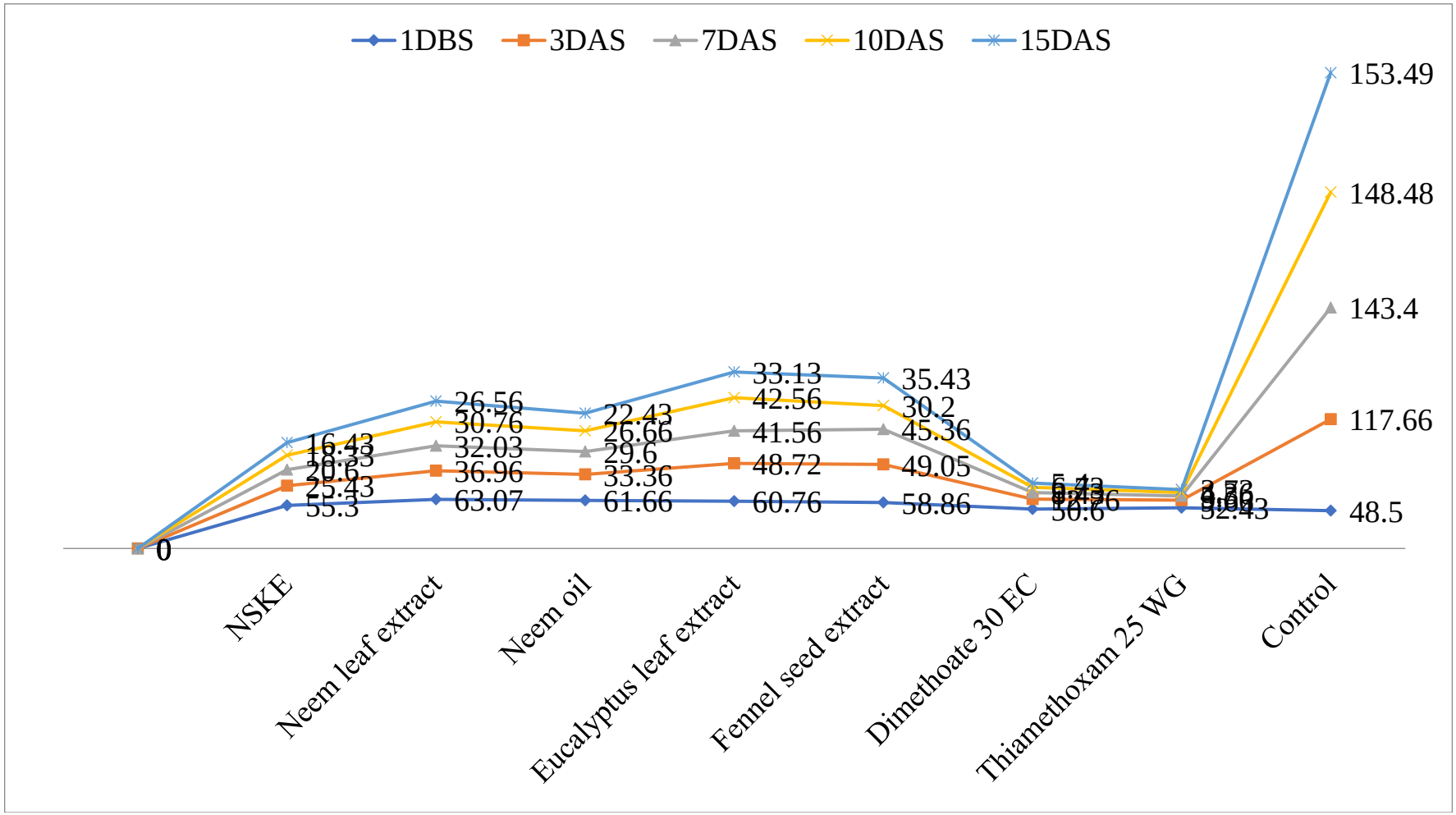

Fig. 1. Population of aphid after first spray

Table 2. Impact of treatment on the population of mustard aphids, *Lipaphis erysimi* (Kalt.) after second spray

T. No.	Treatment	Mean population of mustard aphid per 10 cm central twig per plant								
		Dose	1DBS	3DAS	PROC	7DAS	PROC	10DAS	PROC	15DAS	PROC
1	NSKE	5%	18.76 (4.38)	16.36 (4.10)	90.22	14.70 (3.89)	91.47	11.63 (3.48)	93.89	9.60 (3.17)	95.44
2	*Neem* leaf extract	5%	38.60 (6.25)	24.63 (5.01)	85.28	21.66 (4.70)	87.43	16.46 (4.11)	91.36	13.90 (3.79)	93.40
3	*Neem* oil	2%	28.50 (5.38)	23.20 (4.86)	86.14	20.53 (4.58)	88.09	13.60 (3.75)	92.86	12.30 (3.57)	94.16
4	Eucalyptus leaf extract	5%	43.40 (6.62)	32.50 (5.74)	80.58	30.63 (5.57)	82.23	26.60 (5.20)	86.04	23.66 (4.91)	88.77
5	Fennel seed extract	5%	36.46 (6.08)	34.50 (5.91)	79.39	32.53 (5.74)	81.13	29.56 (5.48)	84.49	25.56 (5.10)	87.87
6	Dimethoate 30 EC	1ml/lit	12.46 (3.60)	10.70 (3.37)	93.60	6.33 (2.60)	96.32	4.36 (2.20)	97.71	2.33 (1.68)	98.89
7	Thiamethoxam 25WG	0.2 g/lit	11.80 (3.50)	9.60 (3.17)	94.26	4.86 (2.31)	97.18	3.16 (1.91)	98.34	1.23 (1.31)	99.41
8	Control		158.53 (12.61)	167.43 (12.95)		172.40 (13.14)		190.63 (13.82)		210.73 (14.53)	
	SE(m) ±		0.316	0.154		0.187		0.228		0.251	
	C.D at 5%		0.966	0.470		0.572		0.698		0.770	

DOS (Date of spraying) 26-02-2022
DBS (Day before spray)
DAS (days after spray)
PROC (Per cent over control)
Figure within parentheses is square root (√ X+.5)

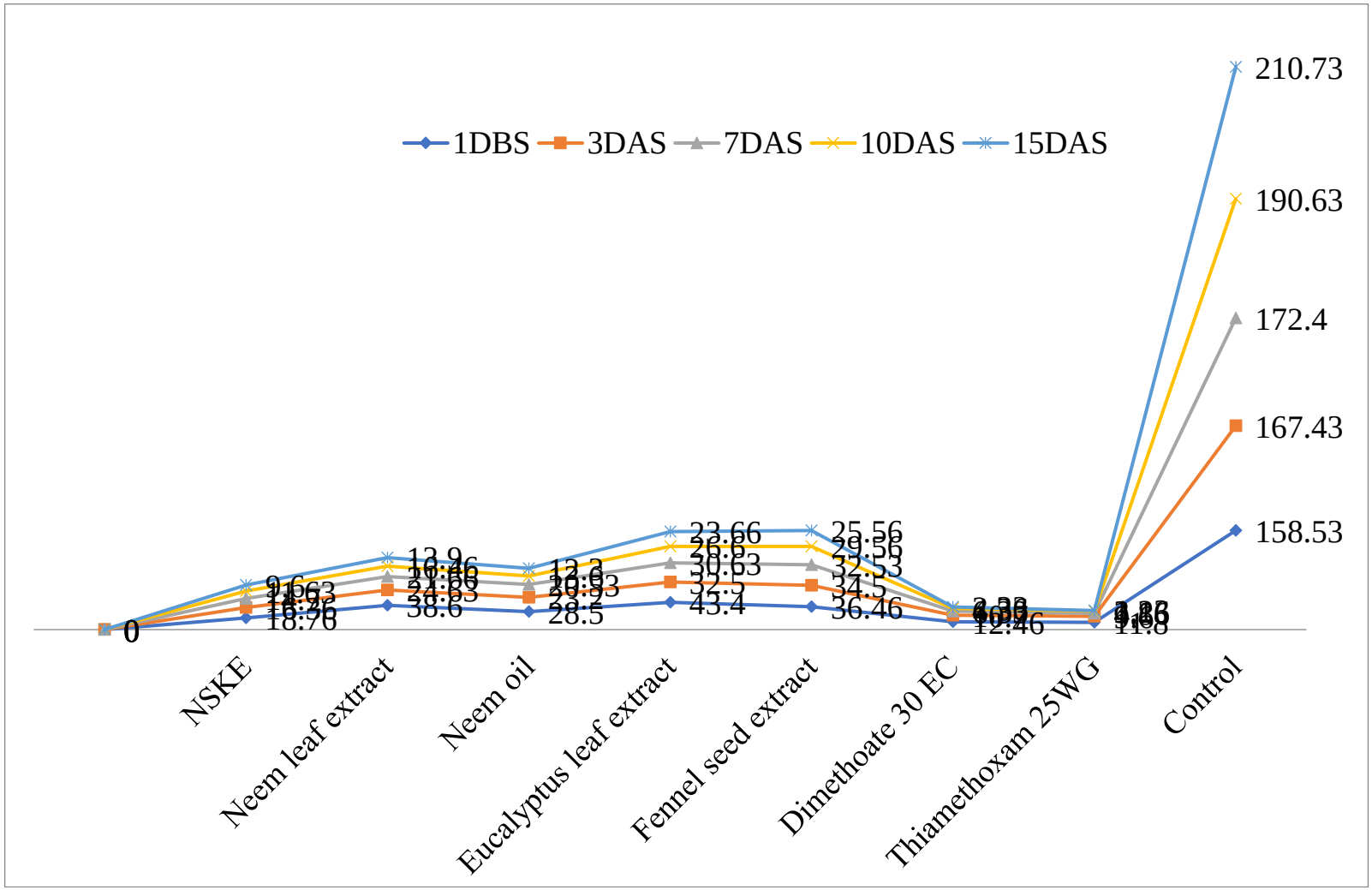

Fig. 2. Population of aphid after second spray

Table 3. Economics of management of treatment against mustard aphid *Lipaphis erysimi* (Kalt)

T. No.	Treatment and dose	Amount of insecticide on hectare basis	Cost of insecticide (Rs/hac)	Total expenditure (Rs/ha)	Total yield (kg/ha)	Gross income (Rs.)	Net return Over control	Net income (Rs./ha)	ICBR
1	NSKE @ 5 %	31.25 (kg)	5000	6204	1683	78259	46918	40714	1:6.56
2	*Neem* leaf extract @ 5%	31.25 kg	4656	5860	1508	70122	38781	32921	1:5.61
3	*Neem* oil @ 2%	12.25 lit	5145	6349	1595	74167	42826	36477	1:5.74
4	Eucalyptus leaf extract @5 %	31.25 kg	2656	3860	1191	54381	23040	19180	1:4.96
5	Fennel seed extract @ 5 %	31.25 kg	4375	5579	1120	5280	20739	15160	1:2.71
6	Dimethoate 30 EC @ 1 ml/lit	600 ml	683	1887	1762	81933	50592	48705	1:25.81
7	Thiamethoxam 25 WG @ 0.2 g/lit	120.00 (gram)	135	1339	1873	87094	55753	54414	1:40.63
8	Control				674	31341			

- *Spray volume 600 liters of water. One labour charge (Rs.201 / hac+ sprayer charges Rs.100/ hac)*
- *The total expenditure comprises both labor costs and insecticide expenses. The selling price of mustard is set at 4650*

Leaf Extract, and Fennel Seed Extract were successful in curbing mustard aphid populations seven days post the second spray. Thiamethoxam and Dimethoate emerged as the most potent insecticides, followed by NSKE and the plant extracts.

Ten days after the second spray, observations indicated that both Thiamethoxam 25 WG @ 0.2 g/lit and Dimethoate 30 EC @ 1.0 ml/lit were extremely effective against mustard aphids, yielding populations of 3.16 and 4.36 aphids on each 10 cm section of the central twig of a plant, respectively. They achieved impressive reduction percentages over the control, with 98.34% and 97.70%, respectively. Among plant extracts, NSKE @ 5%, *Neem* Oil @ 2%, and *Neem* Leaf Extract @ 5% were equally effective against mustard aphids, yielding populations of 11.63, 13.60, and 16.46 aphids on each 10 cm section of the central twig of a plant, respectively. Similarly, Eucalyptus Leaf Extract @ 5% and Fennel Seed Extract @ 5% were equally effective against mustard aphids, yielding populations of 26.60 and 29.56 aphids on each 10 cm section of the central twig of a plant, respectively. They achieved reduction percentages of 86.04% and 84.49%, respectively, over the control. These findings affirm the potency of Thiamethoxam and Dimethoate as the most effective insecticides against mustard aphids, followed by NSKE, *Neem* Oil, *Neem* Leaf Extract, Eucalyptus Leaf Extract, and Fennel Seed Extract.

The population of mustard aphids was assessed fifteen days after the second spray. Both Thiamethoxam 25 WG at a concentration of 0.2 g/lit and Dimethoate 30 EC at 1.0 ml/lit demonstrated high effectiveness against mustard aphids, resulting in populations of 1.23 and 2.33 aphids on each 10 cm section of the central twig of a plant, respectively. These treatments were found to be highly significantly effective and comparable to each other. Among the plant extracts, NSKE at 5%, *Neem* Oil at 2%, and *Neem* Leaf Extract at 5% also exhibited comparable effectiveness against mustard aphids, with populations of 9.60, 12.30, and 13.90 aphids on each 10 cm section of the central twig of a plant, respectively. These findings further validate the potent insecticidal properties of Thiamethoxam and Dimethoate against mustard aphids. Additionally, NSKE, *Neem* Oil, and *Neem* Leaf Extract showed effectiveness in reducing aphid populations, albeit to a lesser extent when compared to Thiamethoxam and Dimethoate.

3.3 Impact of the Treatment on the Production of Seeds

The efficacy of various treatments in combating mustard aphid was assessed based on the yield of seeds, as outlined in Table 3. All treatments outperformed the control in terms of seed yield. Thiamethoxam 25 WG, at a concentration of 0.2 g/lit, produced the maximum seed yield of 18.73 q/ha. Dimethoate 30 EC, at a concentration of 1 ml/lit, was the next most effective, producing a yield of 17.62 q/ha. NSKE at 5% resulted in a seed yield of 16.83 q/ha, while *Neem* leaf extract at 5% produced 15.08 q/ha. Both of these were comparable to their respective second sprays after 15 days. Eucalyptus leaf extract at 5% resulted in a yield of 11.91 q/ha, and Fennel seed extract at 5% yielded 11.20 q/ha. These last two treatments significantly differed from the rest.

3.3.1 Financial implications of the treatment

The evaluation of financial benefits from each treatment was conducted by comparing their gross income with the control, as depicted in Table 3. Thiamethoxam 25 WG at a concentration of 0.2 g/lit resulted in the highest net income, amounting to Rs 54,414/ha. This was followed by Dimethoate 30 EC at a concentration of 1 ml/lit and NSKE at 5% were subsequently used, resulting in net earnings of Rs 48,705/ha and Rs 40,714/ha, respectively. On the other hand, the treatment with Fennel Seed Extract at 5% led to the lowest net income, totaling Rs 15,160/ha.

3.3.2 Effect of treatment based on ICBR

As per the Incremental Cost Benefit Ratio shown in Table 3, the treatment using Thiamethoxam 25 WG at a concentration of 0.2 g/lit, with a subsequent application after 15 days, exhibited the greatest economic feasibility with a significant benefit ratio of 40:63 compared to other treatments. Not far behind in efficacy are the treatments employing Dimethoate 30 EC at 1 ml/lit and NSKE at 5%, with respective benefit ratios of 25:81 and 6:56, also applied a second time after a 15-day interval.

4. CONCLUSION

Overall, the results of the current studies showed that a number of factors influenced the

occurrence of insects, with temperature, relative humidity, rainfall, and sunshine hours being identified as the main weather-related factors. Factors like the methods of farming, growth stages of the crop, the *Varuna* variety, the species of rapeseed, and weather conditions influenced the presence of mustard aphid. According to a test on the effectiveness of plant extracts and chemicals against mustard aphids, chemical insecticides like Dimethoate and Thiamethoxam were more effective against mustard aphids than plant extracts like NSKE, *Neem* oil, Eucalyptus leaf extract, Fennel seed extract, and *Neem* leaf extract.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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