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Bio-efficacy of novel insecticides against mustard aphid (*Lipaphis erysimi* Kalt.) in mustard crop (*Brassica campestris* L.)

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Abstract
The field experiment was conducted in randomized block design with three replications of nine treatments for a crop season of the year i.e. "*Rabi* 2021-22" at the agricultural research farm of Baba Raghav Das Post Graduate College Deoria Up, India. Different insecticides against *L. erysimi* revealed that all the insecticides were significantly more effective in reducing the population of aphids and thus increasing the yield than control. Higher yield ranged between 9.00 q/ha to 17.50 q/ha and were proved significantly superior over control 6.75 q/ha.
The highest seed yield of 17.50 q/ha was obtained from the imidacloprid 17.8% SL treated plot and it was significantly superior over the rest of the treatments. Cost benefit ratio from the table that thiamethoxam 25 WG ranked first indicating the maximum return Rs 1:23.13 per rupee invested followed by imidacloprid 17.8% SL (1: 17.31) and carbosulfan 25 EC (1:13.15).

Keywords: Efficacy, novel insecticides, mustard aphid (*Lipaphis erysimi*)

1. Introduction
Mustard is one of the most important oil seed crops which has been widely cultivated, originated in the Asia region.
The name mustard is derived from the Latin word mustum. The mustard seed contain 30-46 percent oil which is one of the important sources of edible oil followed by groundnut (Pandey *et al.* 1999) [23]. Mustard seed cakes are also utilized as fertilizers and animal feed (Cheema *et al.* 2018) [10]. The oilseeds crop plays a very significant role in the agricultural economy of our country. India is the largest producer of oilseeds.
Total oilseeds area and production in the country is about 27.00 million hectare and 33.4 million tonnes, respectively with an average yield of 1236 kg per hectare (Anonymous 2020) [5].
Several biotic and abiotic factors are responsible for reducing the yield. Among the several insects infesting the mustard, mustard aphid, *Lipaphis erysimi* (Kalt) is the most serious insect -pest of the mustard crop. Both nymphs and adults suck the cell sap from various parts of the plant like leaves, inflorescence, tender stem and pods and cause economic damage (Rustamani *et al.* 1999) [28]. Infestation of *L. erysimi* on Indian mustard were accountable for reductions on growth and yield parameters including plant height, the number of branches per plant, silique per plant, grain per silique, seed yield, oil content and oil yield (Malik and Deen 1998) [20]. *L. erysimi* causes 35.4 to 96% yield loss, 30.9 percent seed weight loss and 2.75% oil loss (Bakhetia and Sekhon 1989, Singh and Premchand 1995, Bakhetia and Arora 1986, Verma and Singh 1987) [36, 32, 6, 34]. In view of combating the notorious pest, the present investigation was undertaken to study the efficacy of novel insecticides and economics of insecticides against this pest.

2. Materials and Methods
2.1 Plan of the experiment
The present investigation was carried out during the period of *Rabi* season at the field of agricultural research farm of B.R.D.P.G College Deoria Up, India. The research farm is situated at the 26 °6' to 26°48' North latitude and 83°29 ' East longitude. The temperature goes up to 46 °C in the month of May - June and goes down to 5.6 °C in December - January.
The experiment was laid out in a following randomized block design with three replications

having plot size of 2×2 sq.m. with spacing of 30×15 cm. The mustard cultivar used was Pukhraj sown on 2nd week of November and all the practices were followed to raise the good crop. A total of nine treatments including untreated checks were evaluated in RBD with three replications. Two sprays of insecticides at different intervals were pooled to get the desired conclusion are presented in table-2.

2.2. Determination of amount of insecticides

The required amount of insecticides was calculated by using the formula as given below:

$$\text{Required amount of insecticides} = \frac{\text{Water (lit /ha}^{-1}) \times \text{Desired concentration (\%)}}{\text{Strength of insecticide formulation (\%)}}$$

2.3. Application of treatments

All treatments were sprayed with the help of Knapsack Sprayer. The care was taken to avoid drift of spray from one plot to another plot by surrounding the plot with polythene sheets as border at the time of spraying.

2.4. Pre- treatment and post -treatment observation

The crop was regularly monitored to record occurrence of aphid up to ETL (50 aphids /10 cm central twig /plant at terminal stage of crop). Treatments were applied, when mustard aphids were at ETL. The populations of aphids were recorded one day before treatment and 3, 7 and 10 days after treatment at each application of treatments. The incidences of mustard aphid were recorded on five randomly selected plants from each plot by following the appropriate method of observation. The yield was also being recorded from each plot separately to determine the effects of treatment on yield. Besides, the efficacy of insecticides was also calculated in the form of percent reduction of aphid population was calculated after application of insecticidal sprays. The findings of two sprays of percent reduction pooled to get desired conclusions are presented in table -3.

The data was used to compute percent reduction in incidence following Handerson and Tilton (1955) [15] referring to it as a modification of Abbott (1925) [1].

$$\text{Percent efficacy} = \left[1 - \frac{Ta}{Ca} \times \frac{Cb}{Tb}\right] \times 100$$

Where,

Ta = Number of insects on treated plots after insecticidal application

Tb = Number of insects in treated plots before insecticidal application

Ca = Number of insects in untreated plots after insecticidal application

Cb= Number of insects in untreated plots before insecticidal application.

2.5. Statistical analysis

The data obtained from the experiment were statistically analyzed in appropriate programme by the Computer with desired transformation (✓x) in a Randomized Block Design.

3. Results and Discussion

The efficacy of eight insecticides were evaluated under field condition with untreated check against aphid in mustard. All the insecticides proved significantly superior over untreated check at all the intervals of observation. Most of the insecticides showed non – significant variation to each other in their effectiveness at all the intervals of observation after spray. Overall performance of insecticides in current investigation revealed that imidacloprid 17.8 SL and thiamethoxam 25 WG was most effective against aphid, followed by carbosulfan 25 EC, fipronil 5% SC, clipping of infested twigs with neem oil @ 3% and botanicals.

Among the treatments botanicals were recorded as least effective compared to other evaluated treatments.

The results are in agreement with Dikshit and Prasad (2001) [12] and Patil *et al.* (2010) [26] who reported imidacloprid 17.8% SL treated plots were most effective against the aphid population when used as foliar spray.

The results also corroborate Rohilla *et al.* (2004) [27], Mishra and Yadav (2013) [22] and Bhattacharya and Dhar (2008) [9] who reported imidacloprid 17.8% SL as most effective as other insecticides evaluated against mustard aphid. The effectiveness of imidacloprid against mustard aphid was also reported by Gour and Pareek (2003) [14], Dhaka *et al.* (2009) [11] and Kumar *et al.* (2013) [18] obtained maximum control of aphid with the application of thiamethoxam 25 WG followed by imidacloprid 17.8% SL.

The effectiveness of imidacloprid 17.8% SL and thiamethoxam 25 WG were also reported by Mandal *et al.* (2012) [21] and Dhaka *et al.* (2009) [11] corroborates the present findings. Similar findings were also obtained by Patel *et al.* (2018) [24] and Yadav and Singh (2016) [35] who had reported imidacloprid 17.8% SL was most effective among all the tested treatments, which supports the present finding.

The efficacy of carbosulfan 25 EC and fipronil 5% SC were observed least effective against aphid population which are confirmed with findings of Sharma *et al.* (2020) [33] who had also reported carbosulfan and fipronil 5% SC were least effective in reducing the aphid population.

3.1. Percent efficacy of aphid under different insecticidal treatments

Comparative efficacy of various insecticides in respect of percent reduction of aphid, revealed that reduction percent was maximum at days after spray in imidacloprid 17.8 SL treated plots. It was followed by carbosulfan 25 EC, thiamethoxam 25 WG, clipping of infested twig with neem oil @ 3% fipronil 5% SC and acetamiprid 20 SP.

The percent reduction was least recorded in nimbecidine @ 2% treated plots followed by neem oil @ 3%.

Our findings are in close conformity with Patil *et al.* (2010) [26] and Bhargava (2010) [8] who reported a percent reduction in aphid was maximum in imidacloprid 17.8 SL and thiamethoxam 25 WG treated plots.

Our findings are similar in terms of percent efficacy reported by Dotasara *et al.* (2017) [13], who proved imidacloprid 17.8 SL gave highest reduction (85.73 percent) followed by fipronil 5% SC @ 1 ml / lit. (83.65 percent) reduction at 7 days after spray.

Kafle (2015) [17] found that the efficacy of morgosan (a neem-based insecticide) @ 5 ml /lit., the reduction of aphids was 38 – 64%. Locally extracted neem pesticide was found to reduce aphid population up to 53.58% (Abed and Simon, 2015) [15] corroborate the result of present finding when botanicals were compared. Our findings got support from Gaur and Pareek (2003) [14], Agrawal *et al.* (2005) [3] and Singh and Lal (2011) [31] who found NSKE 5%, neem leaf extract 5% and neem oil 2% to be effective in reducing the aphid population.

3.2. Effectiveness of insecticidal treatments against mustard yield

All the treatments increased the yield of mustard in comparison to untreated check. The highest yield was recorded in plot treated with imidacloprid 17.8% SL (17.50 q/ h), followed by thiamethoxam 25 WG (16.75 q / h), carbosulfan 25 EC (16 q /ha), acetamiprid 20 SP (11.75 q /ha), clipping of infested twig with neem oil @3% (11.25 q /ha) and nimbecidine @ 2% (9.00 q /ha). Present results are in close conformity with that of Singh *et al.* (2014) [30] and Ahlawat *et al*. (2018) [4] who recorded maximum yield of mustard in a plot treated with imidacloprid 17.8 SL followed by thiamethoxam 25 WG.

These findings are in partial proximity with the findings of Patel *et al.* (2017) [25], who recorded maximum seed yield of 21.61 q /h in thiamethoxam treated plots showed at par with imidacloprid 17.8 SL (21.43 q/h).

Bhattacharya and Dhar (2008) [9] and Bana *et al*. (2011) [7] also reported the insecticides like imidacloprid and thiamethoxam treated plots increase the seed yield of mustard corroborate the present findings.

3.3. Economics of various insecticidal application

While judging the utility of any insecticide in the pest management programme, it is not only evaluated by its relative potency against the target pest and the period for which its application provides protection to the crops, but the economics of treatments also remains a major consideration. Hence, the benefit cost ratio was also worked out in the present investigation.

The highest additional income was recorded from the plots treated with imidacloprid 17.8% SL (Rs 66650), followed by thiamethoxam 25 WG (Rs 62000) carbosulfan 25 EC (Rs 57350), acetamiprid 20 SP (Rs 31000) and clipping of infested twig with neem oil @3% (Rs 27900). Among the botanicals maximum additional income was observed in nimbecidine @ 2% treated plots (Rs 24800), followed by neem oil @ 3% (Rs 13950).

As the cost benefit ratio is concerned it was maximum with thiamethoxam 25 WG (1: 23.13), followed by imidacloprid 17.8% SL (1: 17.31), carbosulfan 25 EC (1: 13.15), fipronil 5% SC (1: 10.85) and acetamiprid 20 SP (1: 10.21). These findings are in close conformity with that of Hegde *et al*. (2019) [16] who also found maximum return with thiamethoxam 25 WG followed by imidacloprid 17.8% SL. Our findings are in partial agreement with that of Singh *et al*. (2014) [30] and Bhattacharya and Dhar (2008) [9] who also reported better return rupees per rupee invested with application of imidacloprid and thiamethoxam. Our findings are in close conformity with that of Sharma *et al*. (2020) [33] who also recorded comparatively lower C: B ratio in carbosulfan treated plots (9.88 Rs), followed by acetamiprid (9.15 Rs).

Among the botanicals highest C:B ratio was observed in nimbecidine @ 2% treated plots (1: 8.26), followed by clipping of infested twigs with neem oil @ 3% (1: 6.64) and neem oil @ 3% (1: 4.10).) and fipronil (7.97 Rs) per rupee invested.

Ahlawat *et al*. (2018) 4[] recorded a poor C: B ratio with NSKE treated plots (Rs 4.85), followed by neem oil (5.20 Rs) per rupee invested. Similar trends were also observed in the present investigation. Our findings also got support from Kumar *et al*. (2020) [19] who recorded a poor B: C ratio in NSKE 5% treated plots (Rs 3.11), followed by neem oil @ 3% (Rs 2.76), per rupee invested.

The extent of cost of protection and yield obtained is proportional to the extent of benefit achieved. The benefit or loss in particular treatment depends on their cost and corresponding yield.

Table 1: Insecticidal treatments evaluated against mustard aphid

S. N.	Insecticidal treatments	Dose (ml or gm /litre of water)	Trade name	Source of availability	Price of insecticides /litre or kg
1	Imidacloprid 17.8% SL	1 ml/l	Confidor	Bayer Crop Science Pvt. Ltd.	2250
2	Carbosulfan 20% SC	1.5 ml/l	Marshall	FMC	1840
3	Fipronil 5% SC	2 ml/l	Regent	Bayer Crop Science Pvt. Ltd.	1485
4	Thiamethoxam 25 WG	0.5 g/l	Actara	Syngenta	2160
5	Acetamiprid 20% SP	1 gm/l	Proud	Rain Biotech	960
6	Nimbecidine 2%	2 ml/l	Nimbecidine	T. Stanes & Company Limited.	700
7	Neem oil 3%	3 ml/l	Neem oil	Casa De Amor (Ambica biotech company)	600
8	Clipping of infested twig with neem oil 3%	3 ml/l	Neem oil	Casa De Amor (Ambica biotech company)	600
9	Untreated check	Water spray			

Table 2: Population of mustard aphid under different insecticidal treatments (Pooled, 1st & 2nd spray)

Treatment	No. of aphids/10 cm apical twig		
	3 DAS	7 DAS	10 DAS
Imidacloprid 17.8% SL	22.81 (3.87)	12.18 (3.75)	15.41 (3.65)
Carbosulfan 25 EC	18.70 (4.78)	21.52 (4.67)	23.13 (4.60)
Fipronil 5% SC	23.10 (5.55)	32.26 (5.52)	31.11 (5.48)
Thiamethoxam 25 WG	31.21 (4.33)	14.09 (4.14)	19.55 (4.07)
Acetamiprid 20 SP	30.75 (5.75)	29.53 (5.77)	33.25 (5.78)
Nimbecidine @ 2%	58.44 (7.05)	44.26 (7.06)	49.92 (7.07)
Neem oil @ 3%	52.99 (6.83)	42.35 (6.91)	46.81 (6.84)
Clipping + neem oil @ 3%	30.13 (5.87)	30.72 (5.65)	34.75 (5.62)
Untreated control	140.71 (11.72)	148.65 (12.13)	148.82 (12.14)
S.E. (M.)	0.56	0.47	0.48
CD (5%)	1.68	1.42	1.46

*Figure in parentheses are squared root transformed values

*DAS= Days after spray

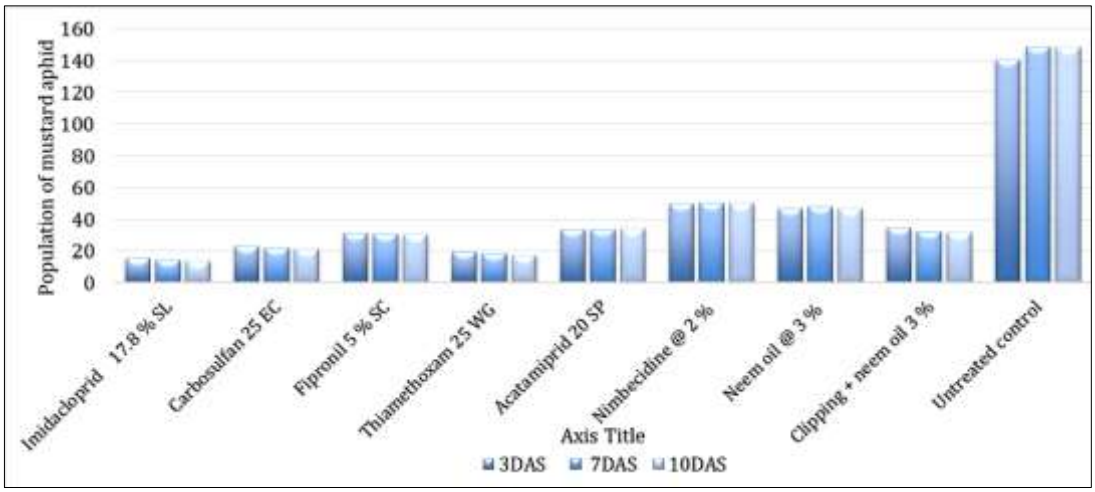

Fig 1: Population of mustard aphid under different insecticidal treatment

Table 3: Percent reduction in aphid under different insecticidal treatments (Pooled)

Treatment	Percent reduction of aphid population		
	3 DAS	7DAS	10 DAS
Imidacloprid 17.8% SL	88.03	89.34	90.03
Carbosulfan 25 EC	84.42	85.61	86.05
Fipronil 5% SC	74.15	75.77	76.05
Thiamethoxam 25 WG	82.79	84.87	85.47
Acetamiprid 20 SP	74.43	75.59	75.31
Nimbecidine @ 2%	57.53	59.74	59.63
Neem oil @ 3%	68.72	69.72	70.36
Clipping + neem oil @ 3%	74.95	77.95	78.26
Untreated control			

Table 4: Economics of insecticides for the control of mustard aphid during *Rabi* 2021 -22

Treatments	Seed yield (q/h)	Yield increase over control (kg/ha)	Additional income (Rs/ha)	Cost of protection for two sprays (Rs/ha)			Net profit (Rs/ha)	ICBR
				Cost of insecticides	Labour charge	Total cost		
Imidacloprid 17.8 SL	17.50	10.75	66650	2250	1600	3850	62800	1:17.31
Carbosulfan 25 EC	16.00	9.25	57350	2760	1600	4360	52990	1:13.15
Fipronil 5% SC	14.75	8.00	49600	2970	1600	4570	45030	1:10.85
Thiamethoxam 25 WG	16.75	10.00	62000	1080	1600	2680	59320	1:23.13
Acetamiprid 20 SP	11.75	5.00	31000	1435	1600	3035	27965	1:10.21
Nimbecidine @2%	10.75	4.00	24800	1400	1600	3000	21800	1:8.26
Neem oil @ 3%	9.00	2.25	13950	1800	1600	3400	10550	1:4.10
Clipping + neem oil @ 3%	11.25	4.50	27900	1800	2400	4200	23700	1:6.64
Untreated check	6.75	-	-	-	-	-	-	-

ICBR = Incremental Benefit Cost Ratio
*Rate of mustard = 6200 Rs / quintal
*Amount of water used = 500 litre /ha
*Labour charge @ 400 Rs / labour
* Clipping charge @ 2, Labour = 800 Rs

4. Conclusion

Many controlling measures are adopted to manage the mustard aphid population below economic injury level like chemical, mechanical, physical, cultural, host plant resistance and biological control. Among these, at severe attack, the chemical control is very important and provides significant control. The major concern in chemical control is the development of Insecticidal resistance, resurgence, pest outbreak etc., against most of the commonly used broad spectrum Insecticides in the field. This has necessitated the use of alternative eco-friendly Insecticides to and newer molecules to sustain the management of insect -pests and to avoid all effects of traditional insecticides. The farmers of this region of North Eastern Uttar Pradesh (Deoria) do not know much about effective insecticides to control pests of mustard crops. They take information from their neighbors, pesticide shopkeepers or other non-informed people about the problem of pests and their management. They also do not know when to use insecticides, how many to spray for effective management. However, there are many types of insecticides available in the local market, which are used indiscriminately by most of the farmers. Evaluation of such insecticides used by most of the farmers will provide practical information about the economic and effective management of mustard pests.

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