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Field evaluation of management strategies against *Lipaphis erysimi* (Kaltenbach) (Homoptera, Aphididae) infesting Indian mustard in Haryana, India

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ABSTRACT: Effectiveness of diverse eco-safe strategies against mustard aphid, *Lipaphis erysimi* (Kaltenbach) infesting Indian mustard was evaluated for two years with 11 treatments viz., *Beauveria bassiana* @ 10^8 CS ml^{-1}, neem seed kernel extract (NSKE) @ 5 per cent, neem oil @ 5 per cent, *B. bassiana* @ 10^8 CS ml^{-1} after clipping of infested twigs (CIT), nimbecidine @ 0.03 per cent, NSKE @ 5 per cent after CIT, neem oil @ 5 per cent after CIT, nimbecidine @ 0.03 per cent after CIT, clipping of infested twigs alone, dimethoate 30 EC @ 625 ml ha^{-1} and control. The pooled data revealed that dimethoate contributed maximum efficacy in reducing *L. erysimi* population over control (89.74 %), followed by *B. bassiana* after CIT (83.16 %) and nimbecidine @ 0.03 per cent after CIT (80.51%). Seed yield (1716 kg ha^{-1}) was maximum in dimethoate, followed by treatments *B. bassiana* @ 10^8 CS ml^{-1} after CIT (1636.5 kg ha^{-1}) and nimbecidine @ 0.03per cent after CIT (1608 kg ha^{-1}), whereas minimum (1211 kg ha^{-1}) in the control. The gross income (Rs 64350 ha^{-1}) and net return (Rs 18017 ha^{-1}) were highest in dimethoate, followed by *B. bassiana* @ 10^8 CS ml^{-1} after CIT with gross income of Rs 61388 ha^{-1} and net return of Rs 13865 ha^{-1}. The incremental cost-benefit ratio was also maximum in dimethoate (1: 19.58), followed by *B. bassiana,* nimbecidine and NSKE treatments (1: 6.33 to 7.27). Results suggest that *B. bassiana* @ 10^8 CS ml^{-1} after CIT and nimbecidine @ 0.03 per cent after CIT can be used as a non- chemical control option as a substitute to chemical control. © 2022 Association for Advancement of Entomology

KEY WORDS: *Beauveria bassiana*, clipping, bio-intensive IPM, cost-benefit ratio

INTRODUCTION

Aphids are nefarious, sap-sucking, soft-bodied insect pests of Brassicaceae members (Guerrieri and Digilio, 2008; Blackman and Eastop, 2017). The mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera, Aphididae) is the most overwhelming sucking insect pest of rapeseed-mustard in India. Worldwide, India placed 1st in the case of the rapeseed-mustard area and occupied 2nd position in production after China. Rapeseed-mustard is economically important as it provides vegetables, animal feed and edible oils (Khavse *et al*., 2014; Jat *et al*., 2019). Mustard has very good nutritional value due to its seed containing proteins (17-25%), fibres (8-10%), and oil (30-33%) (Sudhir *et al*., 2013). Indian mustard (*Brassica juncea* L.) oil contains a high amount of oleic, eicosenoic, and erucic acids (70%) and linoleic and linolenic acids (22 %), and a low amount of palmitic and stearic

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acids (8%) (Kumar, 2015). In India, rapeseed-mustard crops are grown in the area of land 6.69 million hectares with a production of 10.11 million tonnes and productivity of 1511 kg ha^{-1}. In Haryana, it was cultivated on 0.63 million hectares with production and productivity of 1.28 million tonnes and 2027 kg ha^{-1} respectively (Anonymous, 2021).

Mustard aphid suck the cell sap from different parts of the plant viz., leaves, inflorescence, tender stem, and pods. Its substantial attack causes curling of leaves, weak pod formation and undersized grains. Honeydew secreted by this insect pest was liable for the development of sooty mould and reduces the photosynthetic rate (Bakhetia and Sekhon, 1989). Heavy infestation of *L. erysimi* (Fig. 1) causes seed yield loss ranging from 32.62 to 100 per cent (Singh and Sachan, 1999; Sahoo, 2012; Sharma *et al*., 2019; Shrestha *et al*., 2020). Patel *et al*. (2017), Maurya *et al*. (2018), Kumar and Sharma (2020) and Kumar (2021) concluded that the chemical insecticides such as thiamethoxam 25 WG, fenvalerate 20 EC, malathion 50 EC, dimethoate 30 EC, quinalphos 25 EC, chlorpyriphos 20 EC, imidacloprid 17.8 SL, acephate 75 SP, pymetrozine 50 WG, clothianidine 50 WDG and acetamiprid 20 SP were effective in the management of *L. erysimi* in diffrent regions of the country.

The main concern in chemical control is that it causes environmental pollution, adverse effects on human health, resurgence, and toxicity to pollinators and natural enemies (Singh, 2001). This has demanded the use of substitute non- chemical (eco-friendly) strategies viz., Aloe vera leaf extract @10 per cent, neem oil @ 2% followed by *Chilomenes septempunctata* @ 5,000 beetles ha^{-1}, *Verticilium lecanii* @ 10^{8} CS ml^{-1} + clipping of infested twigs, *Beauveria bassiana* @ 10^8 CS ml^{-1} + NSKE @ 5 per cent, tobacco leaf extract @ 10 per cent, eucalyptus leaf extract @ 10 per cent and azadirachtin 1500 ppm @ 1.0 ml $litre^{-1}$ of water for the management of *L. erysimi* on mustard (Yadav and Singh, 2015; Sharma *et al*., 2017; Kumar *et al*., 2020). The present investigation was carried out to evaluate the efficacy of certain environmentally friendly strategies against *L. erysimi* in the mustard ecosystem.

MATERIALS AND METHODS

Field experiment was undertaken in 2019-20 and 2020-21 during *rabi* season in the farmer's field, Kolana village, Aravalli Hills Region, Rewari, Haryana, India. It is located in the south western area of Haryana at 28°12'24.7"N latitude, 76°21'11.0"E longitude, and an altitude of 296 m above sea level. This region falls under semi-arid zones of the country with dry and hot summer as well as severe cold in winter. The surface soils textures at the experimental area are sandy loam. *Brassica juncea* genotype RH 725 taken as the host plant for *L. erysimi* was obtained from the Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Regional Research Station (RRS), Bawal, Rewari, Haryana, India. Experiments were conducted under randomized block design with three replications and 11 treatments (Table 1).

Preparation of Neem seed kernel Extract (NSKE): One kg of dried neem seed kernels crushed and soaked overnight in 10 litres water. Soaked material was filtered through muslin cloth and the volume of the filtrate was made to 10 litres. Dilute to 5 per cent (50 ml decanted solution in one litre of water) and 1 per cent Teepol (10 ml $litre^{-1}$ of water) was added at the time of spraying (Anonymous, 2008).

Preparation of Neem oil: Neem seeds were picked from neem plants, and these seeds were dried and extracted in the oil expeller machine. Crude oil was filtered through muslin cloth and that oil was used as per the requirement of the experiment.

The seeds of genotype *B. juncea* RH 725 were sown in the field in each plot of 4.2×3 m size at 30×10 cm spacing. The crop was raised following standard recommended agronomic practices and irrigations. The treatments were imposed one time at the pod formation stage, when the target pest reached the economic threshold level. The population counts of the aphids in the field were recorded from 10 cm main apical shoot of 10 randomly selected and tagged plants in each plot. Pre-treatment counts refer to the pest population was undertaken one day before the treatments, whereas post-treatment interpretations were made on the first, third, seventh, tenth, and fifteenth days after spray of treatments (Sharma *et al.*, 2017). For calculating the per cent reduction in pest population over control, the following formula was used.

$$\frac{\text{Population in control - Population after spray}}{\text{Population in control}} \text{ X } 100$$

After harvesting the crop, seed yield from each plot was weighed, and then converted into kg ha^{-1}. To determine the economic viability of different treatments, gross income was computed by multiplying seed yield (kg ha^{-1}) with the price of mustard seed @ Rs 37.50 kg^{-1}. The net return over control was worked out by subtracting total cost of treatment from incomes obtained from increased seed yield over control. Total cost of treatment comprised cost of treatment and labour charge. The incremental cost-benefit ratio was calculated by dividing net return over control with total cost of treatment.

The data on pest population was statistically analysed after square root transformation. The critical difference (CD) at 5 per cent level of probability was computed to assess the significant difference amid treatment means by proper method using online statistical software OPSTAT developed by Sheoran *et al*. (1998).

RESULTS AND DISCUSSION

Pre-treatment *L. erysimi* population: The pooled data of two years (*Rabi*, 2019-20 and 2020-21) showed that in pre- treatment (before spray), the pest population (17.34 to 19.88 aphids $plant^{-1}$) scattered non- significantly (P>0.05) (Table 1).

Effect of different treatments on population: The pooled data revealed that all the treatments were significantly ($p< 0.05$) superior in decreasing the infestation of *L. erysimi* over control (Table 1). At 1st day after spray (DAS), treatment T_{10}- dimethoate 30 EC @ 625 ml ha^{-1} was most effective with minimum population of 9.29 aphids $plant^{-1}$, followed by T_4- *B. bassiana* @ 10^8 CS ml^{-1} after CIT (11.05 aphids $plant^{-1}$) and T_8- nimbecidine @ 0.03 per cent after CIT (12.72 aphids $plant^{-1}$), which were statistically at par with each other. After the treatment, T_1- *B. bassiana* @ 10^8 CS ml^{-1} (12.94 aphids $plant^{-1}$) was statistically at par with T_6- NSKE @ 5 per cent after CIT (13.18 aphids), T_7- neem oil @ 5 per cent after CIT (13.52 aphids) and T_5- nimbecidine @ 0.03 per cent (14.23 aphids). Following the next order of efficiency, T_9- CIT (15.15 aphids), T_2- NSKE @ 5 per cent (15.94 aphids) and T_3- neem oil @ 5 per cent (16.54 aphids) treatments were statistically at par with one another. The maximum pest population was recorded in T_{11}- control (21.32 aphids). At 3rd DAS, the minimum pest population (5.30 aphids) was observed in dimethoate 30 EC @ 625 ml ha^{-1} against control (24.14 aphids). Next promising treatments were *B. bassiana* @ 10^8 CS ml^{-1} after CIT (8.30 aphids), nimbecidine @ 0.03 per cent after CIT (9.28 aphids) and *B. bassiana* @ 10^8 CS ml^{-1} (9.55 aphids) and all were statistically at par with one another. There after, treatment NSKE @ 5 per cent after CIT (10.43 aphids) was noted statistically at par with neem oil @ 5 per cent after CIT (11.28 aphids). It was followed by nimbecidine @ 0.03 per cent (12.44 aphids) and NSKE @ 5 per cent (13.79 aphids) and are statistically at par with each other, followed by neem oil @ 5 per cent (14.60 aphids). Treatment CIT was observed least effective (17.40 aphids). Outcomes obtained on the seventh and tenth days after spray showed the same order of effectiveness of various treatments against *L. erysimi*. Dimethoate was the most effective treatment among all the tested, followed by *B. bassiana* @ 10^8 CS ml^{-1} after CIT and nimbecidine @ 0.03 per cent after CIT, while CIT alone was least effective (Table 1).

Observing the inclusive efficacy of different treatments against *L. erysimi* revealed that at the 15th DAS, the lowest number of pest population (4.02 aphids) was observed in dimethoate and was superior to all the remaining treatments. The subsequent promising treatments were *B. bassiana* @ 10^8 CS ml^{-1} after CIT (6.60 aphids) and nimbecidine @ 0.03 percent after CIT (7.64 aphids) and both were statistically at par with each other. Treatment *B. bassiana* @ 10^8 CS ml^{-1} (8.19 aphids) was found statistically at par with NSKE @ 5 per cent after CIT (9.23 aphids plant^{-1}); followed by neem oil @ 5 per cent after CIT (9.95 aphids) and nimbecidine @ 0.03 per cent (10.82 aphids), which were statistically at par with each other. The next effective treatment NSKE @ 5 per cent (11.67 aphids) was statistically at par with neem oil @ 5 per cent (12.97 aphids), however CIT alone was detected least effective (29.28 aphids). The maximum pest population (39.19 aphids plant^{-1}) was registered in control (Table 1).

Pest reduction: Combined results of both the years revealed treatment at 15 DAS, the population reduction was maximum (89.74 %) in dimethoate and was paramount treatment in managing the pest. This is in accordance with Meena *et al*. (2013), Singh *et al*. (2014), Sharma *et al*. (2017), Kumar *et al*. (2020), Kumar and Sharma (2020) and Yadav *et al*. (2021). In the present study *B. bassiana* @ 10^8 CS ml^{-1} after CIT gave 83.16 per cent pest reduction, followed by nimbecidine @ 0.03% after CIT (80.51 %), *B. bassiana* @ 10^8 CS ml^{-1} (79.10%), NSKE @ 5 per cent after CIT(76.45%), neem oil @ 5 per cent after CIT (74.61%), nimbecidine @ 0.03 per cent (72.39%), NSKE @ 5 per cent (70.22%) and neem oil @ 5 per cent (66.90%), whereas CIT was reported least

Table 1. Field efficacy of different treatments against *L. erysimi* in *B. juncea* (Pooled data of *Rabi*, 2019-20 and 2020-21)

Treatments	Population of *L. erysimi* plant^{-1}						Pest reduction (%)
	Before spray	1 DAS	3 DAS	7 DAS	10 DAS	15 DAS	
T_1- *Beauveria bassiana* @ 10^8 CS ml^{-1}	19.88 (4.57)	12.94 (3.73)	9.55 (3.24)	9.07 (3.17)	8.82 (3.13)	8.19 (3.02)	79.10
T_2- Neem seed kernel extract (NSKE) @ 5%	18.80 (4.45)	15.94 (4.11)	13.79 (3.85)	12.90 (3.73)	12.19 (3.63)	11.67 (3.56)	70.22
T_3- Neem oil @ 5%	19.35 (4.51)	16.54 (4.19)	14.60 (3.95)	13.82 (3.85)	13.30 (3.78)	12.97 (3.74)	66.90
T_4-*Beauveria bassiana* @ 10^8 CS ml^{-1} after CIT	17.57 (4.31)	11.05 (3.47)	8.30 (3.05)	7.25 (2.87)	6.83 (2.80)	6.60 (2.76)	83.16
T_5- Nimbecidine @ 0.03%	17.52 (4.30)	14.23 (3.90)	12.44 (3.66)	11.62 (3.55)	11.15 (3.48)	10.82 (3.44)	72.39
T_6- NSKE @ 5% after CIT	17.89 (4.34)	13.18 (3.76)	10.43 (3.38)	10.12 (3.33)	9.62 (3.26)	9.23 (3.20)	76.45
T_7- Neem oil @ 5% after CIT	17.34 (4.28)	13.52 (3.81)	11.28 (3.50)	10.84 (3.44)	10.47 (3.39)	9.95 (3.31)	74.61
T_8- Nimbecidine @ 0.03% after CIT	18.77 (4.45)	12.72 (3.70)	9.28 (3.21)	8.45 (3.07)	7.95 (2.99)	7.64 (2.94)	80.51
T_9- Clipping of infested twigs (CIT)	18.10 (4.37)	15.15 (4.02)	17.40 (4.29)	19.82 (4.56)	23.75 (4.97)	29.28 (5.50)	25.29
T_{10}- Dimethoate 30 EC @ 625 ml ha^{-1}	19.00 (4.47)	9.29 (3.21)	5.30 (2.51)	4.62 (2.37)	4.15 (2.27)	4.02 (2.24)	89.74
T_{11}- Control (unsprayed)	18.52 (4.42)	21.32 (4.72)	24.14 (5.01)	29.82 (5.55)	31.78 (5.73)	39.19 (6.34)	-
CD at 5%		0.24	0.25	0.23	0.23	0.24	-
SE(m)	0.06	0.08	0.08	0.08	0.08	0.08	-

Figures in parentheses are square root transformed value; DAS- Day after spray ; CIT - clipping of infested twigs

Table 2. Comparative economic analysis of different treatments against *L. erysimi* in *B. juncea* (Pooled data of *Rabi*, 2019-20 and 2020-21)

Treatments	Total cost (Rs. ha^{-1})	Seed yield (kg ha^{-1})	Gross income (Rs. ha^{-1})	Income over control (Rs. ha^{-1})	Net returns over control (Rs. ha^{-1})	cost-benefit ratio
T_1- *Beauveria bassiana* @ 10^8 CS ml^{-1}	1810	1587.5	59550	14137	12327	1: 6.81
T_2- Neem seed kernel extract (NSKE) @ 5%	1350	1475	55313	9900	8550	1: 6.33
T_3- Neem oil @ 5%	2000	1460.5	54788	9375	7375	1: 3.69
T_4-*Beauveria bassiana* @ 10^8 CS ml^{-1} after CIT	2110	1636.5	61388	15975	13865	1: 6.57
T_5- Nimbecidine @ 0.03%	1590	1528.5	57338	11925	10335	1: 6.50
T_6- NSKE @ 5% after CIT	1650	1574.5	59063	13650	12000	1: 7.27
T_7- Neem oil @ 5% after CIT	2300	1552	58200	12787	10487	1: 4.56
T_8- Nimbecidine @ 0.03% after CIT	1890	1608	60300	14887	12997	1: 6.88
T_9- Clipping of infested twigs (CIT)	300	1235.5	46350	937	637	1: 2.12
T_{10}- Dimethoate 30 EC @ 625 ml ha^{-1}	920	1716	64350	18937	18017	1:19.58
T_{11}- Control (unsprayed)	-	1211	45413	-	-	-

Note: Labour charge for the spray of each insecticide= Rs. 450 ha^{-1}; Labour charge for applying treatment Clipping of infested twigs (cultural method) = Rs. 300 ha^{-1}; Price of mustard = Rs. 37.50 kg^{-1}.

Fig. 1 *L. erysimi* infested plants of *B. juncea*

effective (25.29%). The results of Sharma *et al*. (2017) and Yadav *et al*. (2021) corroborated with present findings, who suggested that treatments viz., *B.bassiana* @ 10^8 CS ml^{-1} (79.44 and 82.42%), *B. bassiana* @ 10^8 CS ml^{-1}+ clipping infested twigs (84.09 and 85.88 %), NSKE @ 5 per cent (82.63 and 80.19 %) and NSKE @ 5 per cent+clipping infested twigs (87.77 and 83.74 %) controlled *L. erysimi* infestation. Chanchal and Lal (2009) and Kumar *et al*. (2020) reported that NSKE 5, neem oil 2 and 3 per cent reduced the population of *L. erysimi* effectively.

Seed yield and economics: Maximum seed yield (1716 kg ha^{-1}) was noted in dimethoate treatment as compared to the control (1211 kg ha^{-1}). It was followed by *B. bassiana* @ 10^8 CS ml^{-1} after CIT (1636.5 kg ha^{-1}), nimbecidine @ 0.03 per cent after CIT (1608 kg ha^{-1}), *B. bassiana* @ 10^8 CS ml^{-1} (1587.5 kg ha^{-1}), NSKE @ 5 per cent after CIT (1574.5 kg ha^{-1}), neem oil @ 5 per cent after CIT (1552 kg ha^{-1}), nimbecidine @ 0.03 per cent (1528.5 kg ha^{-1}), NSKE @ 5 per cent (1475 kg ha^{-1}) and neem oil @ 5 per cent (1460.5 kg ha^{-1}), whereas minimum was registered in CIT alone (1235.5 kg ha^{-1}) (Table 2). Sharma *et al*. (2017), Kumar *et al*. (2020) and Yadav *et al*. (2021) observed maximum seed yield in dimethoate 30 EC @ 625 ml ha^{-1}.

Highest gross income (Rs 64350 ha^{-1}) and maximum net return over control (Rs 18017 ha^{-1}) was obtained in treatment dimethoate with the maximum incremental cost-benefit ratio (ICBR) of 1:19.58. Among non-chemical treatments, treatment *B.bassiana* @ 10^8 CS ml^{-1} after CIT recorded maximum gross income (Rs 61388 ha^{-1}) and net return over control (Rs 13865 ha^{-1}) but ICBR with 1:6.57 ICBR, whereas NSKE @ 5 per cent after CIT gave 1:7.27 ICBR. The next promising treatments were nimbecidine @ 0.03 per cent after CIT (Rs 60300 and 12997 ha^{-1}), *B. bassiana* @ 10^8 CS ml^{-1} (Rs 59550 and 12327 ha^{-1}) and NSKE @ 5 per cent after CIT (Rs 59063 and 12000 ha^{-1}), whereas minimum was noted in treatment CIT alone (Rs 46350 and 637 ha^{-1}), respectively. ICBR in the treatment nimbecidine @ 0.03 per cent after CIT was 1: 6.88 and found economically viable after treatment NSKE @ 5 per cent after CIT, followed by treatment *B. bassiana* @ 10^8 CS ml^{-1} (1: 6.81), while treatment CIT alone was computed least economical (1: 2.12) (Table 2). Sharma *et al*. (2017) also reported highest cost-benefit ratio in dimethoate (1:14.92), followed by NSKE @ 5 per cent + clipping of infested twig (1:13.81). Sahoo (2012), Meena *et al*. (2013) and Kumar *et al*. (2020) reported dimethoate as economical treatment.

Conclusively, the chemical treatment, dimethoate 30 EC @ 625 ml ha^{-1}demonstrated high efficacy in comparison to non- chemical treatments in managing *L. erysimi* population. However, non- chemical treatments such as *B. bassiana* @ 10^8 CS ml^{-1} after CIT and nimbecidine @ 0.03 per cent after CIT were efficacious in suppressing the aphid infestation and recommended as an excellent substitute to chemical controls for the aphid management as a result avoids detrimental effects of chemical insecticides on human health, non- target organisms and environment.

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