



Management of mustard aphid with exogenous application of salicylic acid in Nagaon district of Assam

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<https://doi.org/10.56093/job.v17i2.10>

Received date : 31 May 2026; Revised date : 04 July 2026; Accepted date : 06 July 2026

Abstract

Mustard aphid, *Lipaphis erysimi* (Kaltenbach), is one of the most destructive insect pests of rapeseed–mustard, causing substantial yield losses under field conditions. A field experiment was conducted during three consecutive rabi seasons (2023–24, 2024–25 and 2025–26) at the Zonal Research Station, Shillongani, Assam Agricultural University, to evaluate the efficacy of exogenous application of salicylic acid against mustard aphid and its effect on coccinellid predators, seed yield and economics. The experiment was laid out in a randomized block design with five treatments comprising salicylic acid at 0.5 mM (69 ppm), 1.0 mM (138 ppm) and 1.5 mM (207 ppm), thiamethoxam 25 WG @ 0.1 g L⁻¹ and an untreated control. The pooled results revealed that salicylic acid at 1.5 mM was the most effective treatment, recording the lowest aphid population of 14.09, 17.96, 15.30 and 5.93 aphids plant⁻¹ at 3, 7, 10 and 14 days after spray (DAS), respectively. The treatment resulted in the highest reduction over control (56.59%) and produced the maximum seed yield (1509.44 kg ha⁻¹), which was statistically at par with thiamethoxam 25 WG @ 0.1 g L⁻¹ (1503.89 kg ha⁻¹). Economic analysis indicated that salicylic acid at 1.5 mM generated the highest net return (Rs. 64,087.28 ha⁻¹) and benefit-cost ratio (2.17). The treatment also supported a higher population of coccinellid predators during both flowering (2.40 predator's plant⁻¹) and silique formation stages (3.27 predators plant⁻¹) compared with thiamethoxam 25 WG @ 0.1 g L⁻¹. The findings suggest that foliar application of salicylic acid at 1.5 mM effectively suppresses mustard aphid infestation, enhances yield and profitability, and conserves natural enemies, making it a promising eco-friendly alternative for sustainable mustard aphid management.

Keywords: *Brassica juncea*, coccinellid predators, induced resistance, *Lipaphis erysimi*, salicylic acid, mustard aphid, seed yield, sustainable pest management

Introduction

Rapeseed–mustard is one of the most important oilseed crops globally and plays a pivotal role in ensuring edible oil security, particularly in India. The crop is widely cultivated for its high-quality edible oil and contributes substantially to the agricultural economy of the country. India exhibits diverse edible oil consumption patterns, with mustard–rapeseed oil being predominantly consumed in the eastern and northern regions, while groundnut, sesame, and coconut oils are preferred in other parts of the country (DFPD, 2023). Despite being a major producer of oilseeds, India continues to depend heavily on imports to meet its edible oil requirements. Approximately 56% of the country's edible oil demand is met through imports, of which more than half comprises

palm oil and palmolein (DFPD, 2023). During 2022–23, edible oil imports reached 164.7 lakh tonnes, representing a 17.39% increase over the previous year (Agricultural Statistics, 2022). The growing demand for vegetable oils, driven by population growth, changing dietary preferences, and industrial utilization, highlights the need to enhance domestic oilseed productivity (Dotaniya *et al.*, 2025; Sivakumar & Alexzander 2025). Among the cultivated *Brassica* species, *Brassica juncea*, *B. napus*, and *B. rapa* are the most economically important oilseed crops and together contribute substantially to global rapeseed–mustard production (Chattopadhyay *et al.*, 2005). Rapeseed–mustard is one of the most important oilseed crops in India, ranking second only to soybean and contributing approximately 36% of the nation's edible oil production (Kumar *et al.*, 2025). The crop is extensively

cultivated across major mustard-growing states, including Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, Bihar, West Bengal, Odisha, and Assam (Kumar & Chauhan, 2005). Owing to its high oil content and nutritional value, mustard contributes significantly to human nutrition and rural livelihoods. However, the productivity of mustard is constrained by several biotic stresses, particularly insect pests. More than 38 insect species have been reported to infest rapeseed–mustard crops, although only a few attain economic importance (Bakhetia & Sekhon 1989; Purwar *et al.*, 2004). Among them, the mustard aphid, *Lipaphis erysimi* (Kaltenbach), is regarded as the most destructive pest, causing severe damage from seedling emergence to crop maturity. Aphid infestation adversely affects plant growth by extracting sap from tender shoots, leaves, inflorescences, and developing siliquae, resulting in poor pod formation and reduced seed development (Ali & Rizvi 2008; Ali *et al.*, 2009). Yield losses due to mustard aphid have been reported to range from 35–90%, with severe infestations causing losses exceeding 90% and significantly reducing oil content (Verma & Singh 1987; Biswas & Das 2000; Rohilla *et al.*, 2004; Patel *et al.*, 2014).

Management of mustard aphid has traditionally relied on chemical insecticides because of their rapid and effective control. However, indiscriminate and repeated application of insecticides has resulted in environmental contamination, insecticide resistance, pest resurgence, and the destruction of beneficial natural enemies such as coccinellid predators and parasitoids. Consequently, there is an urgent need to develop sustainable and eco-friendly approaches that effectively suppress aphid populations while conserving beneficial arthropods and maintaining ecological balance. Salicylic acid (SA), an important endogenous phytohormone, regulates plant defence responses against both pathogens and insect herbivores. It activates systemic acquired resistance (SAR), induces defence-related genes, and modulates several biochemical pathways that strengthen the plant's innate defence system, thereby reducing insect colonization and feeding (Molinari 2007). Besides its role in plant immunity, SA also regulates beneficial plant–microbe interactions that enhance plant growth and resilience under biotic stress (Benjamin *et al.*, 2022). Although several studies have demonstrated the defensive role of SA under controlled conditions and against different insect pests, information on its field efficacy against mustard aphid in rapeseed–mustard is limited, and systematic field validation under the agro-climatic conditions of Assam is largely lacking.

Therefore, the present investigation was undertaken to evaluate the efficacy of exogenous application of salicylic

acid against mustard aphid under field conditions in Assam. The study aimed to assess its influence on aphid population suppression, conservation of coccinellid predators, seed yield, and economic returns, and to determine its potential as an eco-friendly alternative to conventional insecticides for sustainable mustard aphid management.

Materials and Methods

Experimental site and duration

A field experiment was conducted during three consecutive *Rabi* seasons, viz., 2023–24, 2024–25 and 2025–26, at the Tokowbari Farm of the Assam Agricultural University -Zonal Research Station, Shillongani, Nagaon, Assam, India (26.356° N latitude and 92.631° E longitude). The study was undertaken to evaluate the efficacy of exogenous application of salicylic acid against mustard aphid, *Lipaphis erysimi* (Kaltenbach), and its effect on natural enemies, seed yield and economics of mustard cultivation.

Experimental design and treatments

The experiment was laid out in a randomized block design (RBD) with five treatments replicated three times. The individual plot size was 4.2 m × 3.0 m. Mustard (*Brassica juncea* L.) was sown during the first fortnight of November following the recommended package of practices of Assam Agricultural University, except for plant protection measures. Rapeseed variety TS-38 was sown at a spacing of 30 cm between rows and 10 cm between plants with a seed rate of 1.0 kg per bigha. The treatments evaluated were: T₁: Salicylic acid 0.5 mM (69 ppm); T₂: Salicylic acid 1.0 mM (138 ppm); T₃: Salicylic acid 1.5 mM (207 ppm); T₄: Thiamethoxam 25 WG @ 0.1 g L⁻¹ of water; and T₅: Untreated control. The treatments were imposed as foliar sprays at the initiation of aphid infestation. Sprays were applied using a knapsack sprayer fitted with a hollow-cone nozzle, at a spray volume of 500 L ha⁻¹, ensuring uniform coverage of the crop canopy. The salicylic acid used in the study was of analytical grade (HiMedia) and procured from a commercial supplier. The required concentrations (0.5, 1.0 and 1.5 mM) were prepared freshly by dissolving the calculated quantity of salicylic acid in distilled water immediately before application. Thiamethoxam 25 WG was obtained from a registered commercial manufacturer and applied at the recommended dose (0.1 g L⁻¹ of water). All treatment solutions were prepared separately and applied as foliar sprays using a knapsack sprayer.

Recording of aphid population

The population of mustard aphid, *L. erysimi*, was recorded

one day before treatment application and subsequently at 1, 3, 7, 10 and 14 days after spraying (DAS). Only one spray was imposed during the initial appearance of aphid. Observations were taken from ten randomly selected plants in each plot. The number of aphids present on the terminal shoot and primary branches of each selected plant was counted, and the mean aphid population per plant was calculated.

Observation on natural enemies

The abundance of coccinellid predators (grubs and adults) associated with mustard aphid was recorded during the flowering and siliqua formation stages of the crop. Observations were taken from the same ten randomly selected plants per plot, and the mean number of predators per plant was worked out. The observations were recorded at weekly intervals during the peak aphid infestation period.

Yield and economic analysis

At maturity, the crop from each net plot area was harvested separately, and seed yield was recorded. The yield data were converted into kilogram per hectare (kg ha^{-1}). Economic analysis of different treatments was carried out based on the prevailing Minimum Support Price (MSP) of mustard. Gross return, net return and benefit-cost ratio (BC ratio) were calculated using standard procedures. The increase in yield over the untreated control was also determined.

Statistical analysis

The data recorded on aphid population, natural enemy abundance and seed yield were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design. Aphid population data were square root transformed [$\sqrt{(x + 0.5)}$] prior to analysis to stabilize variance and satisfy the assumptions of ANOVA. Statistical analyses were performed using the transformed data, whereas the original (untransformed) means are presented in the tables for ease of interpretation. Treatment means were separated using Tukey's Honest Significant Difference (HSD) test at $P \leq 0.05$ level of significance. Data from individual years as well as pooled data across years were analyzed to determine treatment effects. Prior to pooling the data, a combined ANOVA over three years was performed. Since the treatment $\times$ year interaction was non-significant ($P > 0.05$), the data were pooled and subjected to combined analysis. The coefficient of variation (CV%), standard error of mean [SE(m)] and critical difference (CD) at the 5% probability level were computed wherever applicable.

Results and Discussion

Effect of salicylic acid on mustard aphid population

The pooled data over three consecutive years (2023–24 to 2025–26) demonstrated that foliar application of salicylic acid significantly suppressed mustard aphid, *Lipaphis erysimi* (Kaltenbach), populations compared with the untreated control (Table 1). Prior to treatment imposition, aphid populations did not differ significantly among treatments, indicating uniform infestation levels across the experimental plots. However, significant treatment effects became evident following application. At 1 day after spraying (DAS), all salicylic acid treatments and thiamethoxam 25 WG @ 0.1 g L^{-1} recorded lower aphid populations than the untreated control. The suppression effect became more pronounced from 3 DAS onwards. Among the treatments, salicylic acid at 1.5 mM consistently recorded the lowest aphid population throughout the observation period, with 14.09, 17.96, 15.30 and 5.93 aphids plant^{-1} at 3, 7, 10 and 14 DAS, respectively. The standard insecticidal treatment, thiamethoxam 25 WG @ 0.1 g L^{-1} , also effectively reduced aphid populations, recording 27.24, 27.80, 25.85 and 16.59 aphids plant^{-1} at the corresponding observation intervals. In contrast, the untreated control maintained significantly higher aphid populations throughout the study period. The highest reduction in aphid population over control (56.59%) was recorded with salicylic acid at 1.5 mM, which was marginally superior to thiamethoxam 25 WG @ 0.1 g L^{-1} (56.02%). These results indicate that salicylic acid at higher concentrations effectively suppresses mustard aphid infestation and may induce host plant resistance mechanisms against aphid attack. Plants establish beneficial associations with endophytes, arbuscular mycorrhizal fungi, and nitrogen-fixing rhizobia, which not only promote plant growth and development but also enhance tolerance to various biotic and abiotic stresses.

Salicylic acid (SA), a key endogenous phytohormone, plays a central role in regulating plant–microbe symbiotic interactions and activating defence responses against pathogens (Benjamin *et al.*, 2022). Beyond its role in disease resistance, SA is recognized as a key signalling molecule involved in systemic acquired resistance (SAR) and the activation of plant defence pathways. It enhances resistance against insect herbivores by inducing defence-related genes and modulating multiple biochemical and physiological mechanisms, which may reduce aphid colonization, feeding, and subsequent population development. Collectively, these SA-mediated responses strengthen the plant's innate defence system, thereby

Table 1: Effect of exogenous salicylic acid application on the abundance of mustard aphid, *Lipaphis erysimi*, and seed yield of mustard (pooled mean of 2023–24 to 2025–26)

Symbol	Treatments	1DBS	1DAS	3DAS	7DAS	10DAS	14DAS	Yield	IOC
T ₁	Salicylic acid 0.5 mM (69 ppm)	70.74	68.88 ^a	52.98 ^b	49.37 ^b	48.40 ^b	42.70 ^b	1051.22 ^c	9.07
T ₂	Salicylic acid 1.0 mM (138 ppm)	68.23	67.94 ^a	28.08 ^a	29.08 ^a	27.00 ^a	19.03 ^a	1215.11 ^b	26.04
T ₃	Salicylic acid 1.5 mM (207 ppm)	69.01	66.84 ^a	14.09 ^c	17.96 ^c	15.30 ^c	5.93 ^c	1509.44 ^a	56.59
T ₄	Thiamethoxam 25 WG @ 0.1 g L ⁻¹	69.80	66.78 ^a	27.24 ^a	27.80 ^a	25.85 ^a	16.59 ^a	1503.89 ^a	56.02
T ₅	Control	71.70	72.33 ^b	70.40 ^d	68.59 ^d	69.43 ^d	68.01 ^d	963.89 ^d	—
	CV (%)	—	0.45	1.05	5.37	4.55	3.16	4.70	—
	LSD (P=0.05)	NS	0.49	2.95	2.97	1.71	2.17	111.28	—

*IOC= Increase over control; DBS= Day before spray; NS= Non-significant,

Means followed by the same superscript letter(s) within a column are not significantly different at P = 0.05 according to Tukey's Honest Significant Difference (HSD) test at P ≤ 0.05.

improving plant resilience against insect attack (Molinari 2007). Similar findings were reported by Mony *et al.* (2017), who observed that increasing concentrations of salicylic acid significantly reduced aphid infestation in mustard by enhancing physiological and biochemical defense mechanisms. Likewise, Nazar *et al.* (2015) demonstrated that exogenous application of salicylic acid improved stress tolerance and physiological performance in mustard through enhanced proline accumulation and regulation of defense-related metabolic processes.

Effect on seed yield and economics

Significant differences in seed yield were observed among the treatments (Table 2). The highest seed yield was recorded with salicylic acid at 1.5 mM (1509.44 kg ha⁻¹), which was statistically at par with thiamethoxam 25 WG @ 0.1 g L⁻¹ (1503.89 kg ha⁻¹) and significantly superior to the lower concentrations of salicylic acid and the untreated control. The enhanced yield under salicylic acid treatment may be attributed to reduced aphid infestation and improved physiological efficiency resulting from activation of plant defense and growth-promoting mechanisms. The present findings corroborate those of Yadav *et al.* (2024) and Kalita *et al.* (2025), who reported that foliar application of salicylic acid significantly improved growth, physiological parameters and yield attributes of Indian mustard. Salicylic acid has been shown to enhance photosynthetic efficiency, nutrient assimilation and stress tolerance, ultimately contributing to higher crop productivity. Similarly, Nazar *et al.* (2015) reported that salicylic acid alleviated drought-induced reductions in growth and photosynthesis in mustard through enhanced proline accumulation, improved nitrogen and sulphur assimilation, and reduced ethylene production.

The economic analysis further confirmed the superiority of salicylic acid at 1.5 mM (Table 2). This treatment

generated the highest gross return (Rs. 93,585.28 ha⁻¹), net return (Rs. 64,087.28 ha⁻¹) and benefit-cost ratio (2.17), followed by thiamethoxam 25 WG @ 0.1 g L⁻¹ with a net return of Rs. 62,258.18 ha⁻¹ and a BC ratio of 2.01. The untreated control recorded the lowest economic returns. The greater profitability associated with salicylic acid treatment resulted from its effective aphid suppression and consequent enhancement of seed yield. These findings are particularly important in the context of increasing global demand for edible oils and oilseed crops. Sivakumar and Alexzander (2025) highlighted that rising consumption of vegetable oils and expansion of biofuel industries are driving the need for technologies that improve oilseed productivity and profitability. Furthermore, Jakhar *et al.* (2025) reported significant improvements in growth, yield and economic returns of mustard through improved nutrient management practices, emphasizing the importance of integrated approaches for enhancing crop productivity. The higher seed yield observed in the present study may also be associated with improvements in yield-attributing characters. Devi *et al.* (2025) reported that the number of siliquae on the main shoot and primary and secondary branches exerted strong positive direct effects on seed yield in Indian mustard. Reduction in aphid infestation by salicylic acid may have facilitated better assimilate partitioning towards reproductive structures resulting in enhanced seed production.

The abundance of coccinellid predators was significantly influenced by the treatments (Table 3). During the flowering stage, salicylic acid at 1.0 mM recorded the highest predator population (2.70 predators plant⁻¹), followed by salicylic acid at 1.5 mM (2.40 predators plant⁻¹), whereas the lowest population was observed in thiamethoxam 25 WG @ 0.1 g L⁻¹-treated plots (1.63 predators plant⁻¹). A similar trend was observed during the siliqua formation stage, where salicylic acid at 1.5

Table 2: Economics of yield (pooled mean of 2023–24 to 2025–26)

Symbol	Treatments	Yield (kg ha ⁻¹)	Gross return (Rs. ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Net return (Rs. ha ⁻¹)	BCR
T ₁	Salicylic acid 0.5 mM (69 ppm)	1051.22	65175.64	28428.00	36747.64	1.29
T ₂	Salicylic acid 1.0 mM (138 ppm)	1215.11	75336.82	28963.00	46373.82	1.60
T ₃	Salicylic acid 1.5 mM (207 ppm)	1509.44	93585.28	29498.00	64087.28	2.17
T ₄	Thiamethoxam 25 WG @ 0.1 g L ⁻¹ 25 WG @ 0.1 g L ⁻¹	1503.89	93241.18	30983.00	62258.18	2.01
T ₅	Control	963.89	59761.18	27893.00	31868.18	1.14

(MSP of mustard: Rs.6200/q)Effect of salicylic acid on coccinellid predators

mM supported the highest coccinellid population (3.27 predators plant⁻¹), significantly exceeding all other treatments. In contrast, thiamethoxam 25 WG @ 0.1 g L⁻¹ recorded the lowest predator abundance. The higher survival and abundance of coccinellid predators in salicylic acid-treated plots suggest that salicylic acid is comparatively safer to beneficial arthropods than conventional insecticides. Since salicylic acid acts through induction of plant defense responses rather than direct insecticidal toxicity, it is less likely to adversely affect natural enemy populations. Conservation of natural enemies is a key component of sustainable pest management. The present study demonstrated that salicylic acid not only reduced aphid infestation but also preserved predator populations, thereby strengthening ecological pest regulation. The simultaneous suppression of aphid populations and conservation of coccinellid predators highlights the potential of salicylic acid as an eco-friendly component of integrated pest management (IPM) programmes in mustard. The higher abundance of coccinellid predators recorded in salicylic acid-treated plots indicates that this treatment is comparatively safer to beneficial arthropods and supports the conservation of natural enemies in mustard ecosystems. Conservation

of predators and parasitoids is an important component of sustainable pest management, as these natural enemies contribute significantly to the suppression of aphid populations. Similar observations were reported by Borkakati *et al.* (2019a), who demonstrated that habitat manipulation in cabbage ecosystems enhanced the abundance of natural enemies and reduced pest incidence. Likewise, Borkakati *et al.* (2019b) reported that habitat manipulation practices in brinjal created favourable conditions for natural enemy activity, resulting in improved pest regulation.

The present findings are further supported by Pradhan *et al.* (2020a), who reported that eco-friendly pest management approaches, including biological interventions, effectively reduced insect pest populations in toria while conserving beneficial organisms. Pradhan *et al.* (2020b) documented a diverse assemblage of predators and parasitoids associated with mustard ecosystems in Assam and emphasized their important role in regulating insect pest populations. Similarly, Pradhan *et al.* (2020c) observed that the abundance of natural enemies was closely associated with fluctuations in insect pest populations and environmental conditions,

Table 3: Effect of salicylic acid on coccinellid predator abundance (grubs + adults per plant) in mustard (2023–24 to 2025–26)

Symbol	Treatments	2023-24		2024-25		2025-26		Pooled mean	
		FS	SFS	FS	SFS	FS	SFS	FS	SFS
T ₁	Salicylic acid 0.5 mM (69 ppm)	2.00 ^{ab}	1.90 ^c	1.70 ^c	2.10 ^b	2.20 ^b	2.50 ^b	1.97 ^{bc}	2.17 ^{bc}
T ₂	Salicylic acid 1.0 mM (138 ppm)	2.90 ^a	2.80 ^{ab}	2.40 ^{ab}	2.80 ^a	2.80 ^a	2.60 ^b	2.70 ^a	2.73 ^{ab}
T ₃	Salicylic acid 1.5 mM (207 ppm)	2.40 ^{ab}	3.30 ^a	3.00 ^a	3.10 ^a	1.80 ^{bc}	3.40 ^a	2.40 ^{ab}	3.27 ^a
T ₄	Thiamethoxam 25 WG @ 0.1 g L ⁻¹ 25 WG @ 0.1 g L ⁻¹	1.60 ^b	1.70 ^c	1.70 ^c	1.50 ^c	1.60 ^c	1.70 ^c	1.63 ^c	1.63 ^c
T ₅	Control	1.90 ^{ab}	2.30 ^{bc}	2.00 ^{bc}	1.90 ^{bc}	2.10 ^b	2.40 ^b	2.00 ^{bc}	2.20 ^{bc}
	SE(m) ±	0.300	0.329	0.300	0.308	0.223	0.265	0.219	0.236
	LSD (P=0.05)	0.860	0.940	0.856	0.878	0.630	0.760	0.620	0.670

FS = Flowering stage; SFS = Siliqua formation stage

#Means followed by the same superscript letter(s) within a column are not significantly different at P = 0.05 according to Tukey's Honest Significant Difference (HSD) test at P d" 0.05

highlighting their ecological significance in mustard agroecosystems. The enhanced predator population observed under salicylic acid application in the present study is consistent with the findings of Pradhan *et al.* (2026), who reviewed the seasonal dynamics of insect pests and natural enemies in mustard and emphasized the importance of conserving beneficial arthropods for sustainable pest management. Furthermore, Borkakati *et al.* (2026) reported that habitat manipulation strategies significantly reduced mustard aphid infestation while promoting coccinellid predators and other natural enemies, thereby strengthening ecological pest regulation. The simultaneous suppression of aphid populations and conservation of coccinellid predators observed in the present investigation highlights the potential of salicylic acid as an eco-friendly component of integrated pest management programmes for sustainable mustard production.

Overall, the findings clearly indicate that foliar application of salicylic acid at 1.5 mM (207 ppm) was the most effective treatment, providing aphid suppression, seed yield and economic returns comparable to thiamethoxam 25 WG @ 0.1 g L⁻¹ while maintaining significantly higher populations of coccinellid predators. Therefore, salicylic acid at 1.5 mM may be considered a promising, environmentally safe and sustainable alternative for the management of mustard aphid in rapeseed–mustard ecosystems.

Conclusion

The present investigation demonstrated that exogenous application of salicylic acid effectively suppressed mustard aphid, *Lipaphis erysimi* (Kaltenbach), and improved the productivity and profitability of mustard cultivation. Among the treatments evaluated, salicylic acid at 1.5 mM (207 ppm) proved to be the most effective, recording the lowest aphid population at successive post-treatment observations and achieving the highest reduction over control (56.59%). The treatment also produced the maximum seed yield, net return and benefit-cost ratio, which were comparable to those obtained with the standard insecticide thiamethoxam 25 WG @ 0.1 g L⁻¹. In addition to its effectiveness against mustard aphid, salicylic acid at 1.5 mM supported a higher abundance of coccinellid predators, indicating its compatibility with natural biological control agents and its potential role in conservation of beneficial insects. The findings suggest that salicylic acid-mediated induced resistance can serve as an eco-friendly and sustainable approach for mustard aphid management. Therefore, foliar application of salicylic acid at 1.5 mM (207 ppm) may be recommended as a promising alternative or complementary strategy to

conventional insecticides for integrated pest management (IPM) in mustard.

Acknowledgement

The authors are grateful to the Director, ICAR–Indian Institute of Rapeseed–Mustard Research (ICAR–IIRMR), Bharatpur, Rajasthan, for providing the necessary facilities and support for conducting the study. The financial assistance received under the All India Coordinated Research Project (AICRP) on Rapeseed–Mustard is gratefully acknowledged. The authors express their sincere gratitude to Dr. Sarwan Kumar, Principal Investigator and Principal Entomologist (Oilseeds), Department of Entomology, Punjab Agricultural University, Ludhiana–141004, Punjab, India, for his valuable guidance, encouragement and technical support throughout the investigation. The authors are also thankful to the Director of Research (Agri), Assam Agricultural University, Jorhat, Assam, for providing the necessary facilities, infrastructure and institutional support for the successful execution of the research programme.

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