Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 47 Issue 3 May 2026 pp. 636-642
DOI: http://doi.org/10.22438/jeb/47/3/MRN-5865

J. Environ. Biol., 2026
© Triveni Enterprises, Lucknow (India)
Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Efficacy of novel insecticides against major insect pests of potato in Assam

P. Mili[1], S. Bhagawati[1]*, K. Choudhury[1], K. Sarmah[2], P. Sutradhar[3], U. Phukan[1] and E.B. Devi[1]

[1]*Department of Entomology, Assam Agricultural University, Jorhat-785 013, India*
[2]*Department of Biochemistry, Assam Agricultural University, Jorhat-785 013, India*
[3]*Department of Agronomy, Assam Agricultural University, Jorhat-785 013, India*

Received: 18 August 2025 **Revised:** 05 November 2025 **Accepted:** 28 February 2026

***Corresponding Author Email:** sudhansubhagawati@gmail.com ***ORCiD:** https://orcid.org/0000-0002-9440-5425

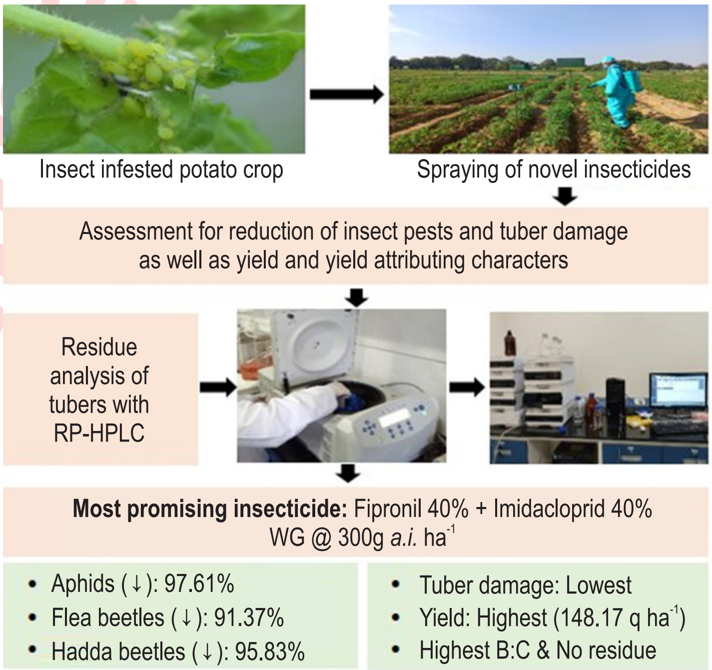
Abstract

Aim: Studying the efficacy of novel insecticides against major insect pests of potato.

Methodology: Two consecutive sprays were performed for six novel insecticides in potato and the per cent reduction of both sucking and foliage feeding insects as well as reduction in tuber damage by subterranean insects was calculated out. Additionally, residue of the most promising insecticide was also estimated using RP-HPLC to determine its safety.

Results: Among the tested insecticides, Fipronil 40% + Imidacloprid 40% WG @ 300g *a.i.* ha^{-1} significantly reduced the incidence of aphids (97.61%), flea beetles (91.37%) and hadda beetles (95.83%) as well as registered lowest tuber damage on both weight and number basis (2.44 and 2.43%, respectively) resulting in a marked increase in marketable tuber yield (148.17 q ha^{-1}) and economic return (2.33). Residue of imidacloprid and fipronil in potato samples was found to be 0.1828 mg kg^{-1} and 0.0093 mg kg^{-1}, respectively, at the time of harvest, which was recorded below the Codex MRL value.

Interpretation: The insecticidal formulation, *i.e.,* Fipronil 40% + Imidacloprid 40% WG when applied @ 300 g *a.i.* ha^{-1} can effectively manage both aboveground and subterranean insect pests of potato due to its dual mode of action with a residue level below MRL values in tubers at harvest signifying a cost effective and environment friendly management option for the potato growers of Assam.



Key words: Evaluation, Fipronil, Imidacloprid, Insect pests, Insecticide, Potato crop

Triveni Enterprises (Educational Services Set-up)

How to cite: Mili, P., S. Bhagawati, K. Choudhury, K. Sarmah, P. Sutradhar, U. Phukan and E.B. Devi: Efficacy of novel insecticides against major insect pests of potato in Assam. *J. Environ. Biol.*, **47**, 636-642 (2026).

Introduction

Potato is the fourth largest food crop grown worldwide and is well known for its ease of cultivation and high nutritive as well as commercial value. As per the recent statistics, the global production of potato was 375 million tonnes in 2022 with India ranking 2^{nd} by the production of 56 million tonnes potato (FAO, 2024). Potato is commercially cultivated in almost all the states of India, and based on its cultivation practices, India is divided into 8 potato growing zones (Bhardwaj *et al.*, 2022). Despite having substantial acerage, the production and productivity of the crop in India is still in an infant stage. Among various bottlenecks, the damage inflicted by various insect pests associated with this crop is a key factor resulting in annual loss of approximately 10-20 per cent of overall production (Kishore and Misra, 2001). More than 100 species of insects have been found to be associated with the crop which severely impact the commercial value (Chandel *et al.,* 2022).

Sap feeding insects like aphids, whiteflies, leafhoppers, thrips and leaf feeding insects like armyworm, slender burnished brass moth, hairy caterpillars, hadda beetles, flea beetles, blister beetles, etc., are of major importance (Chandel *et al.,* 2022). Potato is also prone to many subterranean insects like white grubs, cutworms, Oriental army ants, mole crickets and termites which inflict severe loss in commercial cultivation (Verma *et al.,* 2001; Konar *et al.,* 2005; Bhattacharyya *et al.,* 2014a; Bhattacharyya *et al.,* 2014b; Bhattacharyya *et al.,* 2015). Occurrence of both these group of aboveground and subterranean pests under field conditions makes the management stretagies practically challenging. Research has advanced in the line of developing various management strategies including cultural, physical, biological and chemical practices in various parts of the country (Bhattacharyya *et al.,* 2017; Borkakati *et al.,* 2020; Naga *et al.,* 2021; Shah *et al.,* 2022; Dumala *et al.,* 2023), however, these studies largely focus on the management of individual pest species. Insecticides being the most effective management option against above and below ground potato pests, no single insecticide has so far been reported in the country to address both the pest groups simultaneously.

Moreover, relying on specific insecticides for each targeted pests increases the cost of production and also indiscriminate use of insecticides can lead to harmful pesticide residues posing risk to both human health and environment. In recent years, studies have reported to manage either the group of insects in potato through insecticides (Natikar *et al.,* 2022; Kahar *et al.,* 2025; Yadav *et al.,* 2025), however, information on residue persistance in tubers are largely lacking concerning the safety issues among the endusers. This indicates a clear research gap in identifying a single and effective insecticides with least residue risks for managing both above and below ground pests of potato. Therefore, the present study intended to evaluate novel insecticides against both the group of insect pests and their performance in yield and yield attributing characters along with the assessment of pesticide residues for safe use.

Materials and Methods

Study area: Field experiment was carried out in the Instructional cum Research (ICR) Farm, followed by the laboratory studies at the Soil Arthropod Pests, Department of Entomology, Assam Agricultural University (26°47' N, 94°12' E), Jorhat, Assam, India during 2023-24.

Experiment description and application of treatments: Potato crop (Variety: *Kufri Khyati*) was grown by following the recommended package of practices for rabi crops of Assam (2023) at the ICR Farm based on the previous experience of infestation by both above ground and subterranean insect pests. Six insecticides with recommended doses *viz.,* Clothianidin 50 WDG @ 120 g *a.i.* ha^{-1}, Thiamethoxam 25 WG @ 80 g *a.i.* ha^{-1}; Imidacloprid 70 WG @ 300 g *a.i.* ha^{-1}; Fipronil 40%+ imidacloprid 40% WG @ 300 g *a.i.* ha^{-1}, fipronil 0.3 G @ 50 g *a.i.* ha^{-1} and chlorantraniliprole 0.4 GR @ 100 g *a.i.* ha^{-1} were selected for conducting the experiment based on their novel mode of action and potentiality to manage different insect pests (Nath *et al.,* 2025). The first four insecticides were mixed with water and drenched in ridges of the crop whereas the later two insecticides were mixed with pulverized soil and applied in ridges as basal application during 1^{st} and 2^{nd} earthing up in the evening hours (4-5 p.m.). Alongside, a control (without treatment) plot was also maintained for comparison. Each treatment was replicated thrice with individual plot size of 9 m^2.

Efficacy of insecticides against aboveground pests: Both sap and foliage feeding insect pests were recorded from ten randomly selected tagged plants/ plot at pre-treatment and on 3^{rd}, 5^{th}, 10^{th} and 20^{th} days after the twice insecticide application, *i.e.,* during 1^{st} earthing up and 2^{nd} earthing up. Finally, the per cent reduction in insect pest population over control application of each treatment was calculated by using the formula given by Henderson and Tilton (1955).

Efficacy of insecticides against subterranean insect pests: After harvesting, the total per cent of tuber damage both in weight and number basis caused by major subterranean insect pests like white grubs, oriental army ants, *Dorylus orientalis* and cutworm, *Agrotis ipsilon* was calculated by using the formula given by Bhattacharyya *et al.* (2017). The damaged tubers were counted based on the symptoms caused by these pests as depicted in Fig. 1.

Efficacy of insecticides on yield and economics of the crop: After harvesting, the total quantity of potatoes as well as the potatoes fit for commercialization were separately counted and expressed as total and marketable yield in quintals/ hectare of land area. Finally, the value of benefit from the marketable potato and the cost of cultivation for each treatment was separately calculated and expressed as benefit cost ratio (B:C).

Fig. 1: Damage symptoms of potato tuber by different subterranean insect pests. (A) White grubs creating C shaped clear eating mark; (B) Oriental army ant creating minute holes in the potato peel; (C) Cutworm creating straight feeding hole

Analysis of insecticide residue in harvested tubers: Residues of most promising insecticide capable of managing both aboveground and subterranean insect pests was determined in the harvested potato samples prepared through QuEChERS method with slight modifications (Ahmed *et al.,* 2014). The residue of the targeted insecticides in the QuEChERS extracted sample was estimated by Reversed Phase-High Performance Liquid Chromatography (RP-HPLC) run with a mobile phase comprising of acetonitrile: water (60:40 v/v) at a flow rate of 0.5 ml min^{-1} at 270 nm with C18 column and Diode Array Detector (DAD), standardized by spiking potato samples with known concentrations of insecticide.

Statistical analyses: Data were analysed using Fisher's method of analysis of variance (ANOVA) for Randomized Block Design (Panse and Sukhatme, 1978). The per cent values pertaining to tuber infestation on weight and number basis were angular transformed prior to perform ANOVA (Gomez and Gomez, 1984), and finally the level of significance among the treatments were ascertained at 5 per cent probability.

Results and Discussion

Data on reduction of aerial pest population due to insecticidal treatment are given in Table 1 where major emphasis was laid on aphids (*Aphis gossypii*), hadda beetles (*Epilachna vigintioctopunctata*) and flea beetles (*Monolepta signata*) as they were found in abundance during the experimental period. Among the tested insecticides, fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.* ha^{-1} had significantly reduced the incidence of aphids (86.60 and 97.61%), hadda beetles (73.62 and 95.83%) and flea beetles (74.16 and 91.37%) after 1st and 2nd insecticide application, respectively. However, application of imidacloprid 70 WG @ 300 g *a.i.* ha^{-1} emerged as the second-best insecticide, which reduced both the aphids (78.05 and 95.55%) and hadda beetles (68.90 and 94.24%) effectively, whereas in case of flea beetles, the second-best insecticide was recorded to be thiamethoxam 25 WG @ 80 g *a.i.* ha^{-1} which reduced the population to the tune of 67.09 and 87.79 per cent after 1st and 2nd insecticide application, respectively. Experimental data pertaining to per cent tuber damage caused by various subterranean insect pests are enumerated in Table 2. Out of all the insecticides tested, the application of fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.* ha^{-1} exhibited significantly lowest per cent of tuber damage (2.44% and 2.43% in weight and number basis, respectively), followed by the application of imidacloprid 70 WG @ 300 g *a.i.* ha^{-1} (4.45% and 4.39%). On the contrary, the control plots registered 26.50 and 24.13 per cent of tuber infestation caused by different soil insects.

The highest reduction percent in the aboveground insect pest population as well as lowest per cent of tuber damage caused by different subterranean insect pests was achieved on applying combined formulation of insecticide *i.e.,* fipronil 40% + imidacloprid 40% WG, which might be due to its dual mode of action, where fipronil blocks the chloride channels of Gamma-aminobutyric acid (GABA)-gated and glutamate-gated regulators that leads to hyper-excitation of nerves and muscles of the targeted insects, while imidacloprid acts on the central nervous system of target insects and prevents acetylcholine from transmission between nerves by blocking the nicotinergic neuronal pathway, which finally results in paralysis and death of insects (Chauhan *et al.,* 2024). Among the two major active ingredients of the said insecticide, imidacloprid primarily exhibit strong systemic and translaminar activity which makes them highly effective against many sucking and subterranean insect pests (Kansal *et al.,* 2025). Additionally, fipronil also boost toxicity by exhibiting contact and stomach action which enhances the efficacy of insecticides against many chewing insect pests (Caccavo *et al.,* 2025). Previous studies have also confirmed the superiority of this combined formulation of insecticide against various aerial leaf and foliage feeding as well as subterranean insects (Patel *et al.,* 2020; Pensiya *et al.,* 2022; Kumar and Pandey, 2023; Hugar and Udikeri, 2024).

The plots treated with fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.* ha^{-1} registered significantly highest total tuber yield (151.92 q ha^{-1}) followed by the plots treated with imidacloprid

Table 1: Efficacy of novel insecticides against aboveground insect pests of potato

Treatments	Dose (g a.i. ha^{-1})	Pre count (Nos.)			Per cent reduction					
					After 1st application of insecticide			After 2nd application of insecticide		
		Aphid	Hadda beetle	Flea beetle	Aphid	Hadda beetle	Flea beetle	Aphid	Hadda beetle	Flea beetle
Clothianidin 50 WDG	120	22.33	8.00	18.67	71.97^{c} (58.35)	54.20^{d} (47.43)	46.12^{f} (42.75)	94.47^{b} (79.42)	88.70^{c} (71.04)	71.42^{f} (57.90)
Thiamethoxam 25 WG	80	22.67	8.00	18.33	67.45^{d} (55.42)	48.63^{e} (44.19)	67.09^{b} (55.30)	92.22^{c} (76.63)	83.74^{d} (67.14)	87.79^{b} (70.09)
Imidacloprid 70 WG	300	22.33	7.67	18.00	78.05^{b} (62.38)	68.90^{b} (56.42)	57.94^{d} (49.66)	95.55^{b} (81.72)	94.24^{b} (78.64)	82.61^{d} (65.68)
Fipronil 40% + Imidacloprid 40% WG	300	22.00	7.33	18.67	86.60^{a} (68.83)	73.62^{a} (59.52)	74.16^{a} (59.90)	97.61^{a} (84.06)	95.83^{a} (80.04)	91.37^{a} (73.64)
Chlorantraniliprole 0.4 GR	100	22.00	7.67	18.67	64.60^{e} (53.65)	62.61^{c} (52.52)	63.59^{c} (53.11)	91.30^{c} (75.81)	93.79^{b} (77.73)	86.52^{c} (68.82)
Fipronil 0.3 G	50	22.67	8.00	18.33	57.30^{f} (49.26)	43.24^{f} (41.05)	55.46^{e} (48.18)	88.68^{d} (72.32)	81.11^{e} (65.15)	80.43^{e} (64.05)
Control	Water spray	22.00	7.67	18.00	-	-	-	-	-	-
S. Ed (±)		1.26	0.70	1.11	0.42	0.59	0.62	0.83	0.62	0.19
CD (p=0.05)		NS	NS	NS	0.92	1.27	1.35	1.80	1.36	0.42

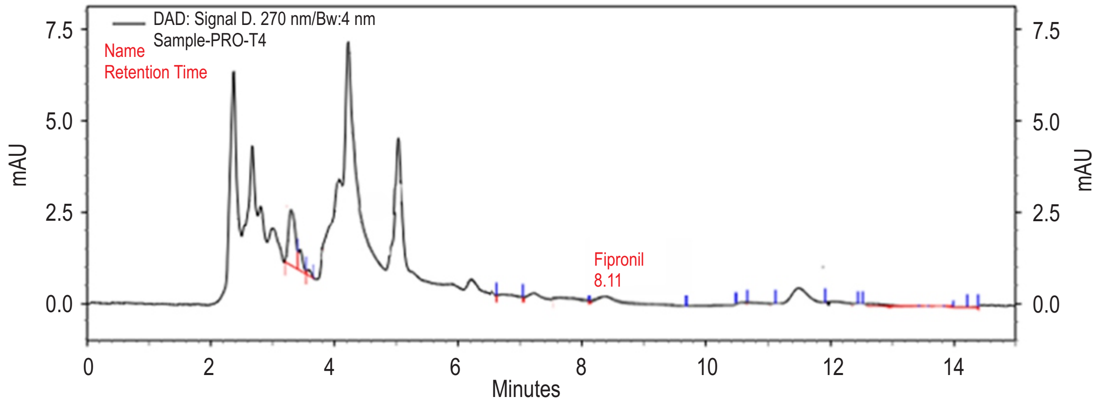
Data are mean of 3 replications; Mean denoted by same letters in the columns are not significantly different; NS: Non-significant

Table 2: Efficacy of novel insecticides against subterranean insect pests of potato

Treatments	Dose (g a.i. ha^{-1})	Per cent tuber damage		Yield		B:C ratio
		Weight basis (%)	Number basis (%)	Total yield (q ha^{-1})	Marketable yield (q ha^{-1})	
Clothianidin 50 WDG	120 g	5.10^{c} (13.02)	4.92^{b} (12.82)	141.33^{bc}	134.11^{b}	2.12
Thiamethoxam 25 WG	80 g	7.74^{d} (16.15)	7.36^{d} (15.74)	136.86^{bcd}	126.26^{c}	2.08
Imidacloprid 70 WG	300 g	4.45^{b} (12.17)	4.39^{b} (12.09)	143.04^{b}	136.67^{b}	2.21
Fipronil 40% + Imidacloprid 40% WG	300 g	2.44^{a} (8.77)	2.43^{a} (8.91)	151.92^{a}	148.17^{a}	2.33
Chlorantraniliprole 0.4 GR	100 g	6.19^{c} (14.40)	6.01^{c} (14.19)	139.94^{bc}	131.28^{bc}	2.11
Fipronil 0.3 G	50 g	9.88^{e} (18.31)	9.17^{e} (14.19)	134.78^{cd}	121.46^{d}	1.78
Control	Water spray	26.50^{f} (30.97)	24.13^{f} (29.42)	131.73^{d}	96.76^{e}	
S. Ed (±)		0.45	0.24	3.52	3.08	
CD (p=0.05)		0.97	0.52	7.66	(6.72)	

Data are mean of 3 replications; Mean denoted by same letters in the columns are not significantly different; NS: Non-significant

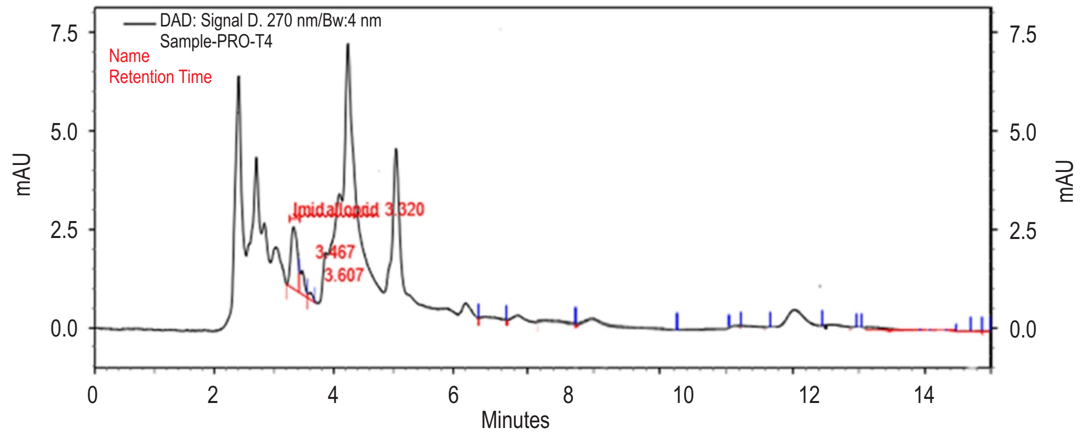
70 WG @ 300g *a.i.* ha^{-1} (143.04 q ha^{-1}) (Table 2). With respect to marketable yield, the maximum (148.17 q ha^{-1}) was recorded in the plots treated with fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.* ha^{-1} which was found to be significantly superior over rest of the insecticidal treatments with a B:C of 2.33. Subsequently, marketable yield of 136.67 and 134.11 q ha^{-1} as well as B:C of 2.21 and 2.12 were recorded in the plots where imidacloprid 70 WG @ 300g *a.i.* ha^{-1} and clothianidin 50 WDG @ 120 g *a.i.* ha^{-1} were applied, respectively. The lowest marketable tuber yield (96.76 q ha^{-1}) was recorded in the control plots. Significant reduction in both above and below ground insect pest population resulting in least damage of plants as well as tubers might be attributed for achieving comparatively higher yield and economic benefit in the fipronil 40% + imidacloprid 40% WG treated plots



DAD: Signal D,270 nm/Bw: 4nm Results

Name	Time	Area	Amount
Fipronil	8.11	142	0.0093

Fig. 2: Chromatogram showing fipronil peak in the harvested potato tubers.



DAD: Signal D, 270 nm/Bw: 4nm Results

Name	Time	Area	Amount
Imidacloprid	3.320	25030	0.18283

Fig. 3: Chromatogram showing imidacloprid peak in the harvested potato tubers.

(Choudhary *et al.,* 2021; Kumar and Pandey, 2022). El Aalaoui *et al.* (2025) also confirmed that effective management of insects in potato field significantly reduced the yield loss, thereby improving the overall crop performances. Field efficacy study of the tested insecticides confirmed that the application of combined formulation *i.e.,* fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.* ha^{-1} significantly reduced both the aerial and subterranean insect pests in potato. However, WHO (World Health Organization) classified both the active ingredients present in the combined formulation of insecticide, *i.e.,* imidacloprid and fipronil as Class II pesticides (moderately hazardous) (Mundhe *et al.,* 2017; Gutta *et al.,* 2019) and hence, the assessment of end user safety is highly essential. Considering this fact, residue analysis was performed for the insecticide to reveal its eco-toxicological effect. Chromatogram peak of the pair of insecticides were detected at 270 nm with a retention time of 8.100 and 3.353 min for fipronil and imidacloprid, respectively. The extracted residue of fipronil and imidacloprid in the potato sample immediately after harvest was 0.0093 and 0.1828 mg kg^{-1} (Fig. 2, 3). This quantified level of residues for both the insecticides in the harvested potato tubers were estimated to be far below the Codex Maximum Residue Limit (MRL) value for fipronil (0.02 mg kg^{-1}) and for imidacloprid (0.50 mg kg^{-1}), respectively signifying its safety for consumption (Chauhan *et al.*, 2013).

The information generated from the present study is important for the potato growers of the country to select insecticide *i.e.* fipronil 40% + imidacloprid 40% WG @ 300 g *a.i.* ha^{-1} having dual mode of action which can effectively manage both aerial (sucking and foliage feeding insect) and subterranean insect pests. Selection of such insecticide will definitely help the farming communities to reduce the dose as well as repeated application of insecticides resulting in managing pests in a cost-effective way. Moreover, both fipronil and imidacloprid act specifically on insect specific receptors thereby making this combined formulation of insecticide comparatively safe for agricultural workers (Simon-Delso *et al.,* 2015).

Residue analysis conducted in the present research also quantified the targeted insecticides below the Codex MRL value, ensuring its safe use for human consumption. Studying the impact of this insecticide molecule towards natural enemies, pollinators, soil microarthropods, soil microbial communities and soil enzyme activities might give more insight about its safety towards the environment.

Acknowledgments

The authors duly acknowledge the help and support received from the Directorate of PG Studies, Assam Agricultural University, Jorhat, Assam towards completion of the research work as well as the Guwahati Biotech Park in performing the RT-HPLC analysis. The authors also sincerely thanks Dr. A. S. Baloda, Network Coordinator, All India Network Project of Soil Arthropod Pests, Rajasthan Agricultural Research Institute, Durgapura, Jaipur for providing financial support during study period.

Authors' contribution: P. Mili: Conducted experiments, collection of data, formal analysis of results; **S. Bhagawati:** Conceptualization of research, methodology designing, conducted experiments, formal analysis of results, original draft preparation; **K. Choudhury:** Methodology designing, conducted experiments related to insecticide residue, draft preparation; **K. Sarmah:** Conducted experiments related to insecticide residue; **P. Sutradhar:** Conducted field experiment; **U. Phukan:** Collection of data, formal analysis of results; **E.B. Devi:** Methodology designing and original draft preparation.

Funding: Not applicable.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Not applicable.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

References

Ahmed, M.A.I., N.S. Khalil and T.A.Abd El Rahman: Determination of pesticide residues in potato tuber samples using QuEChERS method with gas chromatography. *Aust. J. Basic Appl. Sci.,* **8**, 349-353 (2014).

Bhardwaj, V., S. Rawat, J. Tiwari, S. Sood, V.K. Dua, B. Singh, M. Lal, V. Mangal and P. M. Govindakrishnan: Characterizing the potato growing regions in India using meteorological parameters. *Life*, **12**, 1619 (2022).

Bhattacharyya, B., U. Bhuyan and D. Pujari: Management of red ant, *Dorylus orientalis* Westwood (Hymenoptera: Formicidae) in potato. *J. Entomol. Res.,* **38**, 265-267 (2014 a).

Bhattacharyya, B., D. Pujari, U. Bhuyan and A.A.L.H. Baruah: Management of potato cutworm, *Agrotis ipsilon* (Hufnagel) in Assam. *Pestic. Res. J.,* **26**, 82-85 (2014 b).

Bhattacharyya, B., D. Pujari, U. Bhuyan, G. Handique, A.A.L.H. Baruah, S.K. Dutta and S. Tanaka: Seasonal life cycle and biology of *Lepidiota mansueta* (Coleoptera: Scarabaeidae): a serious root-feeding pest in India. *Appl. Entomol. Zool.,* **50**, 435-442 (2015).

Bhattacharyya, B., S. Bhagawati, H. Mishra, D. Gogoi, K. Pathak, S. Bhattacharjee and S. Borkotoki: Evaluation of some granular insecticides against white grub, *Lepidiota mansueta* B. in potato (*Solanum tuberosum* L.). *J. Entomol. Zool. Stud.,* **5**, 1441-1444 (2017).

Borkakati, R.N., D.K. Saikia, G. Kashyap and B.C. Dutta: Evaluation of certain entomopathogenic fungi against soil insect pests of potato. *J. Entomol. Zool. Stud.,* **8**, 889-891 (2020).

Caccavo, V., M. Brienza, S. S. Tsiapou, G. Buttiglieri, R. Rosamilia, P. Fanti, D. Battaglia and V. Trotta: Impact of irrigation with fipronil contaminated waters on zucchini plants and their main insect pest, *Aphis gossypii. J. Environ. Sci.,* **158**, 598–609 (2025).

Chandel, R.S., V.K. Chandla, K.S. Verma and M. Pathania: Insect pest of potato in India: Biology and management. In: Insect Pests of Potato Global Perspectives on Biology and Management (Eds.: A. Alyokhin, S.I. and Rondon, Y. Gao) 2nd Edn., Academic Press, pp. 371-400 (2022).

Chauhan, S.S., S. Agrawal and A. Srivastava: Effect of imidacloprid insecticide residue on biochemical parameters in potatoes and its estimation by HPLC. *Asian J. Pharm. Clin Res.,* **6**, 114-117 (2013).

Chauhan, R., S. Ahlawat, S.S. Yadav, N. Ahlawat and I. Chopra: Residue analysis of premix formulation of fipronil and imidacloprid and its metabolites in hot pepper (*Capsicum annum*). *Indian J. Agric. Sci.,* **94**, 1213-1218 (2024).

Choudhary, S.K., S. Singh, J.K. Bana and B.L. Tandi: Efficacy of newer insecticide against white grub (*Holotrichia consanguinea* B.) in pearl millet under semi arid conditions. *J. Pharm. Innov.,* **10**, 1150-1154 (2021).

Dumala, S., B. Bhattacharyya and B.D. Elangbam: Biocontrol-based management module provided maximum protection in potato against white grub, *Lepidiota mansueta* Burmeister in Assam, India. *Egypt. J. Biol. Pest Control.,* **33**, 4 (2023).

El Aalaoui, M., F.Z. Kamal, S. Rammali, A. Ciobica, C. Albert, B. Novac, V. Burlui and M. Sbaghi: Field evaluation of botanical and biorational insecticides for sustainable management of *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) in potato cultivation. *Front. Sustain. Food Syst.,* **9**, 1-11 (2025).

FAO (Food and Agriculture Organization): World Food and Agriculture - Statistical Yearbook 2024, Rome, pp. 166-170 (2024).

Gomez, K.A. and A.A. Gomez. Statistical Procedures for Agricultural Research, 2nd Edn., John Wiley & Sons, New York, 680 pages (1984).

Gutta, S., J.D. Prasad, K. Gunasekaran and R. Iyadurai: Hepatotoxicity and neurotoxicity of fipronil poisoning in human: A case report. *J. Family Med. Prim. Care.,* **8**, 3437-3439 (2019).

Henderson, C.F. and E.W. Tilton: Tests with acaricides against the brown wheat mite. *J. Econ. Entomol.,* **48**, 157-161 (1955).

Hugar, S.V. and S.S. Udikeri: Efficacy of combi-product fipronil 40%+ imidacloprid 40% WG against leafhopper and thrips in cotton. *Indian J. Entomol.,* **36**, 1-5 (2024).

Kahar, B., P. Mondal, A. Nandi and N. Roy: Evaluation of insecticidal treatment schedules for managing soil pests and enhancing potato yield". *Uttar Pradesh J. Zool.,* **46**, 187-193 (2025).

Kansal, S., S. Dutta and R. Yadav: To study the manufacturing and analysis of pesticide imidacloprid 17.8% SL. *Int. J. Innovat. Res. Tech.,* **11**, 6025-6029 (2025).

Kishore, R. and S.S. Misra: Field evaluation of synthetic insecticides and neem cake for the management of cutworm, *Agrotis ipsilon* (Hfn.), damaging potatoes in different agro-climatic zones of India. *J. Entomol. Res.,* **25**, 31-35 (2001).

Konar, A., S. Paul and P.S. Roy: Management of mole cricket (*Gryllotalpa africana*) infesting potato in West Bengal. *Environ. Ecol.,* **23**, 222 (2005).

Kumar, S. and A.K. Pandey: Bio-efficacy of various insecticides against white grubs (Coleoptera: Scarabaeidae) infesting sugarcane. *Int. J. Trop. Insect Sci.,* **42**, 3319-3325 (2022).

Kumar, S. and A.K. Pandey: Bio-efficacy of newer insecticides against white grub (Coleoptera: Scarabaeidae) infesting soybean crop. *J. Entomol. Res.,* **47**, 368-372 (2023).

Mundhe, S.A., S.V. Birajdar, S.S. Chavan and N.R. Pawar: Imidacloprid poisoning: An emerging cause of potentially fatal poisoning. *Indian J. Crit. Care Med.,* **21**, 786-788 (2017).

Naga, K.C., R.K. Tiwari, S. Subhash, M.K. Lal, A.S. Tetarwal, R. Kumar and A. Bhatnagar: Insect pest of potato ecosystem and their integrated management. In: Recent Advances in Root and Tuber Crops (Eds.: S.J. More, N.A. Giri, S.K. Jabu, V. Chandra and S. Tadigiri). Brillion Publishing, India, pp. 205-226 (2021).

Nath, G., S. Bhagawati, P.K. Kaman, K. Sarmah, B. Gogoi and N.S. Manpoong: Changes in soil faunal pattern as influenced by novel insecticides in Assam. *J. Environ. Biol.,* **46**, 222-229 (2025).

Natikar, P.K., R.A. Balikai and D.N. Kambrekar: Management of major insect pests of potato during rabi season using newer insecticide molecules. *Farm. Manage.,* **7**, 36-45 (2022).

Panse, V.G. and P.V. Sukhatme: Statistical Methods for Agricultural Workers. 2nd Edn., ICAR, New Delhi, India, 145 pages (1978).

Patel, T.M., K.P. Baraiya, P.B. Kaneria and A.H. Jadav: Efficacy of insecticides against white grub, *Holotrichia consanguinea* infesting groundnut. *J. Entomol. Zool. Stud.,* **8**, 759-762 (2020).

Pensiya, M., G.M. Parmar, A.C. Detroja and R.M. Vikani: Efficacy of new molecules of insecticides against aphid, *Aphis gossypii* (Glover) in summer sesame. *Insect Environ.,* **25**, 239-245 (2022).

Shah, M.A., S. Katare, A. Bhatnagar, S. Sharma, M.J. Sadawarti and S.P. Singh: Efficacy of soil insecticides against sucking pests of potato. *Indian J. Entomol.,* **84**, 122-125 (2022).

Simon-Delso, N., V. Amaral-Rogers, L.P. Belzunces, J.M. Bonmatin, M. Chagnon, C. Downs, L. Furlan, D.W. Gibbons, C. Giorio, V. Girolami, D. Goulson, D.P. Kreutzweiser, C.H. Krupke, M. Liess, E. Long, M. McField, P. Mineau, E.A.D. Mitchell, C.A. Morrissey, D.A. Noome, L. Pisa, J. Settele, J.D. Stark, A. Tapparo, H. Van Dyck, J. Van Praagh, J.P. Van der Sluijs, P. R. Whitehorn and M. Wiemers: Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. *Environ. Sci. Pollut. Res.,* **22**, 5-34 (2015).

Verma, S., P.R. Yadav and R. Singh: Distribution of termites and yield loss in potato-based cropping sequence in western Uttar Pradesh. *J. Indian Potato Assoc.,* **28**, 119-120 (2001).

Yadav, D.L., R.R. Meena, B.L. Nagar, B.K. Patidar and S. Sharma: Management of sucking insect pests of potato. *Pest. Res. J.,* **37**, 80-83 (2025).