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Evaluation of Novel Insecticidal Molecules Against Potato Aphids

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ABSTRACT: The study was undertaken at Potato Research Station, S.D. Agricultural University, Deesa, Gujarat (India) between 2020-21 and 2022-23 to assess novel insecticidal compounds for their efficacy against aphids in potato crops. The seven different treatments were evaluated against potato aphid. Based on pooled data of three years. The treatment T_1, involving two foliar spray of Flupyradifurone 200 SL @0.1% at 14-day interval, exhibited the highest statistically significant reduction (77.91%) in aphid populations at fourteen days after last spray and which was found at par with T_4 *i.e.,* Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Flupyradifurone 200 SL @ 0.1 % (14 days after last spray. Furthermore, T_1 demonstrated superior tuber yield (48.81 t/ha) and a higher Benefit-Cost (BC) ratio of 2.10 compared to the untreated control treatment.

Keywords: Aphid, Potato, Insecticide, Novel Molecules, North Gujarat and tuber yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important staple food crops globally, valued for its high nutritional content and versatility in culinary applications. Originating from the Andes region of South America, potatoes have become a crucial component of diets worldwide due to their rich carbohydrate content, essential vitamins (e.g., vitamin C, B-complex vitamins), minerals (e.g., potassium, magnesium), and dietary fiber (Camire *et al.,* 2009). In addition to their nutritional value, potatoes are prized for their ability to grow in diverse climates and soil conditions, making them accessible and economically significant in both developed and developing countries.

The global production of potatoes has steadily increased over the years, reflecting its importance as a staple food. According to the Food and Agriculture Organization (FAO), global potato production reached approximately 470 million metric tons in 2022, with major producers including China, India, Russia, and Ukraine (FAOSTAT, 2022). In India, potatoes are cultivated across various states, with Uttar Pradesh, West Bengal, Bihar, Punjab, and Gujarat being the leading producers. India's diverse agro-climatic zones allow for year-round cultivation, contributing significantly to both domestic consumption and export markets. Gujarat, located in North-Western India, encompasses diverse agro-climatic zones that are highly conducive to potato cultivation. Notably, regions such as North Gujarat, including districts such as Banaskantha, Mehsana, Arvalli and Sabarkantha, offer optimal conditions for the growth of potatoes. The state benefits significantly from well-developed irrigation facilities and favourable soil types, which collectively enhance its productivity in potato farming. Gujarat has emerged as a pivotal contributor to India's potato industry, marked by a consistent growth in cultivation and production over recent years. This growth is supported by the adoption of advanced agricultural practices, such as the use of improved potato varieties and efficient irrigation methods, leading to increased yields and enhanced quality standards.

Potato crops face susceptibility to a range of pests, with Aphids (Hemiptera; Aphididae) are small, soft-bodied insects that weaken the plant by sucking the sap (Van Emden and Harrington 2017). They are among the most destructive crop pests, causing significant damage to crops and reducing crop yields. Aphids utilize piercing-sucking mouthparts to feed on potato plant sap, resulting in diminished plant vigour, distorted growth, and reduced photosynthetic efficiency (Abbot *et al.,* 2018). Their feeding behaviour also facilitates the transmission of virus (Harris and Maramorosch 2014), thereby compounding crop damage and causing substantial economic losses for farmers. Aphids are notorious for their rapid reproduction rates and capacity to transmit viral diseases such as Potato Virus Y (PVY) and Potato Leafroll Virus (PLRV) (Sridhar *et al.,* 2015). Several studies were done between the aphid population and viral disease incidence among them recently Anand *et al.* (2023) reported a positive correlation between aphid and mosaic; leaf roll diseases. These viruses can inflict severe yield reductions and compromise tuber quality, underscoring the critical importance of effective pest management strategies for sustainable potato production (Blackman and Eastop 2000). New pest management and control strategies are being developed in order to meet current and future challenges (Nauen *et al.,* 2015). These pest management practices fall under the following categories "chemical, biological, and cultural" (Barzman *et al.,* 2015). However, the use of chemical pesticides is one that is common due to their availability, efficacy, and ease of use (Deguine *et al.,* 2021). Therefore, the majority of current management practices for *M. persicae* are based on chemical pesticides (Wu and Song 2007). Conventional insecticides have historically served as the primary method for managing aphids in potato cultivation. The sucking pests infesting potato crops have been managed with the use of systemic insecticides ever since the inception of seed plot technique. Commonly used insecticides include dimethoate, imidacloprid, thiamethoxam and phorate (Sharma *et al*., 2012). Nevertheless, challenges including pesticide resistance, environmental considerations, and the management of residues have prompted the pursuit of innovative compounds with improved efficacy and safety profiles. The assessment of novel insecticides seeks to identify alternatives capable of efficiently controlling aphid populations while mitigating negative impacts on beneficial organisms and the environment.

Fig. 1. Aphids below potato leaves.

MATERIALS AND METHODS

The field experiment was conducted to assess the effectiveness of insecticides in controlling aphids in potato crops over three consecutive seasons: *Rabi* 2020-21 to 2022-23 at Potato Research Station, S.D. Agricultural University, Deesa (Gujarat). The study employed a randomized block design with seven treatments, including an untreated control, each replicated five times. Planting was carried out with row spacing set at 50 cm and individual plant spacing at 20 cm. The recommended dose of fertilizers used were 206 kg of nitrogen, 110 kg of phosphorus, and 275 kg of potassium per hectare.

The Treatment were:

T_1	:	Two sprays of Flupyradifurone 200 SL @ 0.1 % at 14 days interval
T_2	:	Two sprays of Diafenthiuron 50 WP @ 0.08 % at 14 days interval
T_3	:	Two sprays of Pymetrozine 50 WG @ 0.06 % at 14 days interval
T_4	:	Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Flupyradifurone 200 SL @ 0.1 % (14 days after last spray)
T_5	:	Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Diafenthiuron 50 WP @ 0.08 % (14 days after last spray)
T_6	:	Foliar sprays of Imidacloprid 17.8 SL @ 0.04 % followed by Thiamethoxam 25WG @ 0.05% (14 days after last spray)
T_7	:	Control

Insecticides were applied using a high-volume knapsack sprayer with a solution rate of 500 liters per hectare.

Aphid population assessments were conducted by recording observations one day prior to spraying (pre-treatment count) and on days 1, 3, 5, 7, and 14 post-spray on five designated plants (including lower, middle, and upper leaves) following the methodology outlined by Healthcote (1972). Based on aphid population data the per cent reduction of pest population over control in the field was worked out by using formula given by Henderson and Tilton (1955).

The percentage data were subjected to transformation into arc sine values to stabilize the variance and ensure the assumptions of statistical analysis were met. The field experiment data were then analyzed using a randomized block design (RBD), as outlined by Gomez and Gomez (1984). Potato tuber yield per plot was noted at the time of harvesting and converted as tonnes per hector.

RESULT AND DISCUSSION

In the year 2020-21 the foliar spray of Flupyradifurone 200 SL @ 0.1 %recorded significantly superior per cent reduction (67.36) than the rest of the treatment at 14th days after first spray while 14th day after second spray, the significantly highest per cent reduction (77.82%) of aphid was also recorded with Flupyradifurone 200 SL @ 0.1 % (two foliar spray at 14 days interval). The next best treatment in sequence was Pymetrozine 50 WG @ 0.06 % followed by Flupyradifurone 200 SL @ 0.1 % (14 days after last spray) which recorded 68.18 per cent aphid reduction (Table 1).

In both the years 2021-22 and 2022-23, treatment T_1*i.e.* two spray of flupyradifuron 200 SL @ 0.1 at 14 days interval exhibited the most substantial percentage reduction in aphid population fourteen days after the second application, which was statistically equivalent to T_4 *i.e.* Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Flupyradifurone 200 SL @ 0.1 %. Following closely in efficacy was treatment T_3 *i.e.* Two sprays of Pymetrozine 50 WG @ 0.06 % at 14 days interval which ranked next in effectiveness among the treatments evaluated (Table 1).

Table 1: The number of aphids before foliar spray and per cent reduction after spray (Year-2020-21, 2021-22 and 2022-23).

Treatment	2020-21				2021-22				2022-23			
	1st Spray		2nd Spray		1st Spray		2nd Spray		1st Spray		2nd Spray	
	Nos before spray	Percent reduction after 14th days	Nos before spray	Percent reduction after 14th days	Nos before spray	Percent reduction after 14th days	Nos before spray	Percent reduction after 14th days	Nos before spray	Percent reduction after 14th days	Nos before spray	Percent reduction after 14th days
T_1	**7.66 *(58.40)	55.16 (67.36)	4.41 (19.00)	62.49 (77.82)	**6.57 *(42.80)	55.35 (67.52)	3.75 (13.60)	63.04 (79.18)	**4.58 *(20.60)	52.16 (62.18)	2.84 (7.60)	61.45 (76.74)
T_2	7.22 (52.00)	46.44 (52.54)	4.99 (24.60)	49.71 (58.20)	6.39 (40.60)	45.11 (50.22)	4.52 (20.00)	51.00 (60.32)	4.73 (22.00)	42.92 (46.43)	3.49 (11.80)	48.45 (56.02)
T_3	7.59 (57.40)	49.17 (57.22)	4.97 (24.40)	52.07 (62.22)	6.42 (41.00)	48.54 (56.15)	4.27 (17.80)	57.09 (70.39)	4.51 (20.00)	46.82 (53.14)	3.11 (9.20)	54.11 (65.56)
T_4	6.98 (48.40)	49.63 (58.03)	4.52 (20.00)	55.73 (68.18)	6.30 (39.60)	49.15 (57.23)	4.14 (16.80)	59.08 (73.54)	4.66 (21.40)	45.32 (50.59)	3.31 (10.60)	58.91 (73.17)
T_5	7.27 (52.80)	48.96 (56.91)	4.79 (22.60)	51.05 (60.46)	6.40 (40.80)	49.41 (57.70)	4.19 (17.20)	51.79 (61.61)	4.53 (20.20)	47.79 (54.88)	3.08 (9.00)	50.96 (60.08)
T_6	7.29 (53.20)	47.72 (54.77)	4.91 (23.80)	56.23 (69.10)	6.59 (43.20)	46.93 (53.38)	4.52 (20.20)	56.92 (70.17)	4.44 (19.40)	44.99 (50.01)	3.17 (9.60)	52.31 (62.64)
T_7	7.28 (52.80)	0.00 (0.00)	7.82 (60.80)	0.00 (0.00)	6.46 (41.40)	0.00 (0.00)	8.10 (65.20)	0.00 (0.00)	4.55 (20.40)	0.00 (0.00)	5.80 (33.20)	0.00 (0.00)
SEd	0.41	1.88	0.26	2.60	0.39	1.85	0.24	2.30	0.31	2.29	0.20	2.75
CD	NS	3.90	0.54	5.39	NS	3.85	0.50	4.77	NS	4.75	0.42	5.71
CV (%)	8.76	6.99	7.91	8.78	9.52	6.97	7.99	7.49	10.70	9.05	9.08	9.34

**Data are transformed values *Data in the parenthesis are original values.

The pooled result shows that prior to the initial spray, no significant discrepancies were observed in aphid counts across all treatments. Following the application, all insecticides exhibited marked superiority over the control. The most notable reduction (65.69%) in aphid population fourteen days after the first spray was noted in T_1 *i.e.,* two sprays of Flupyradifurone 200 SL @ 0.1 % at 14 days interval. Subsequently, T_5 *i.e.* Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Diafenthiuron 50 WP @ 0.08 % (14 days after last spray) showed the next best efficacy, achieving a 56.50% reduction in aphids, which was statistically at par to T_3 *i.e.,* two sprays of Pymetrozine 50 WG @ 0.06 % at 14 days interval, T_4 *i.e.,* Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Flupyradifurone 200 SL @ 0.1 % (14 days after last spray) and T_6 *i.e.,* Foliar sprays of Imidacloprid 17.8 SL @ 0.04 % followed by Thiamethoxam 25WG @ 0.05% (14 days after last spray). Conversely, the least significant reduction in aphid numbers was observed in T_2 *i.e.,* Two sprays of Diafenthiuron 50 WP @ 0.08 % at 14 days interval (Table.2).

The findings regarding the percentage reduction of aphids fourteen days after the second application (Table 2) indicated that the most notable reduction (77.91%) was observed in treatment T_1 *i.e.,* two sprays of Flupyradifurone 200 SL @ 0.1 % at 14 days interval which was followed T_4 *i.e.,* Foliar sprays of Pymetrozine 50 WG @ 0.06 % followed by Flupyradifurone 200 SL @ 0.1 % (14 days after last spray).

The data of per cent reduction of aphid (Fig. 2) indicate that the per cent reduction in aphid at fourteen days after first spray in T_1 was more or less similar in first and second-year data as compared to third year data while the highest per cent reduction of aphid (79.18%) at fourteen days after second spray was noted in T_1 in second year as compared to first and third year. The next best treatment *i.e.,* T_4 show significant higher reduction in first and second year as compared to the third year at fourteen days after first spray while fourteen days after second spray the higher per cent reduction was recorded in the second and third as compared to first year.

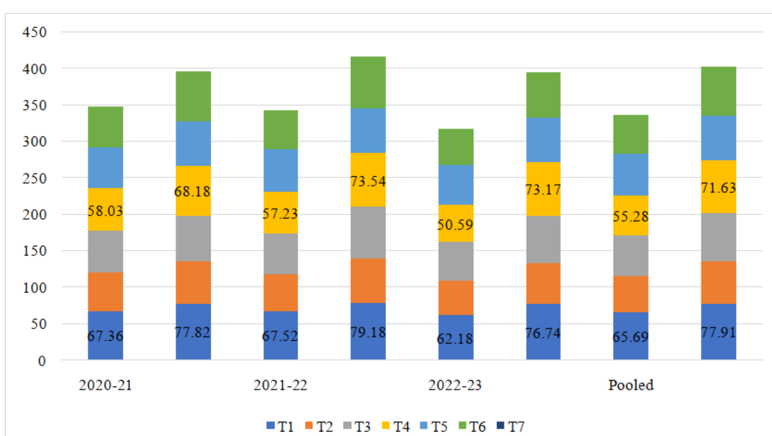

Fig. 2. First reduction of aphid after first and second spray (2020-21, 2021-22 and 2022-23).

The significantly highest total tuber yield (48.81 t/ha) was observed in treatment T_1, which was statistically at par to treatments T_4, T_6, and T_3, yielding 46.86 t/ha, 46.68 t/ha, and 46.17 t/ha, respectively (Table 2).

In terms of economics of different treatments, The T_1, consisting of two foliar spray of flupyradifurone 200 SL at 0.1% at 14-day interval, noted the highest benefit-cost ratio (2.10) which was followed by T_6 *i.e.,* foliar spray of imidacloprid 17.8 SL at 0.04% followed by thiamethoxam 25 WG at 0.05%, showed a competitive economic performance (Table 2).

Table 2: The number of aphids before foliar spray and per cent reduction after spray (Pooled) and economics of different treatments.

Treatment	Pooled				Economics of different of treatments				
	1st Spray		2nd Spray						
	Nos before spray	Percent reduction after 14th days	Nos before spray	Percent reduction after days	Yield (kg/ha)	Total cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
T_1	**6.27 *(40.60)	54.24 (65.69)	3.66 (13.40)	62.35 (77.91)	48.81	185987	390482	204496	2.10
T_2	6.11 (38.20)	44.84 (49.73)	4.33 (18.80)	49.74 (58.18)	43.04	185005	344347	159343	1.86
T_3	6.18 (39.47)	48.19 (55.50)	4.11 (17.13)	54.44 (66.06)	46.17	185681	369389	183708	1.99
T_4	5.98 (36.47)	48.05 (55.28)	3.99 (15.80)	57.93 (71.63)	46.86	185834	374857	189024	2.02
T_5	6.07 (37.93)	48.74 (56.50)	4.02 (16.27)	51.29 (60.71)	44.01	185343	352049	166706	1.90
T_6	6.10 (38.60)	46.56 (52.72)	4.20 (17.87)	55.18 (67.31)	46.68	182823	373418	190595	2.04
T_7	6.10 (38.20)	0.00 (0.00)	7.24 (53.07)	0.00 (0.00)	39.73	181965	317806	135841	1.75
SEd	0.21	1.16	0.14	1.48	1.52	-	-	-	-
CD (T)	NS	2.32	0.47	2.94	3.04	-	-	-	-
CD (Y×T)	NS	NS	0.47	NS	NS	-	-	-	-
CV (%)	9.57	7.68	8.28	8.55	9.26	-	-	-	-

**Data are transformed values *Data in the parenthesis are original values.

Present results are in agreement with findings of Sangamithra *et al.* (2020) flupyradifurone @ 150 and 175 g a.i. ha^{-1} exhibit the excellent control of sucking pests in brinjal agroecosystem without causing any phytotoxicity to the plant. Flupyradifurone 200 SL has been highlighted as a viable alternative to neonicotinoids in cotton ecosystems (Rao *et al*., 2014). Studies have shown that applications of Flupyradifurone 200 SL at rates of 250 g and 200 g active ingredient per hectare provide superior control against leafhoppers, aphids, and whiteflies compared to neonicotinoids like imidacloprid and acetamiprid, even at lower doses of 150 g active ingredient per hectare. Moreover, these treatments have demonstrated efficacy in maintaining high seed cotton yields without adversely affecting natural enemy populations (Prasad, 2017). In brinjal cultivation at Rahuri, Maharashtra, Flupyradifurone 200 SL applied at rates of 125 g, 150 g, and 175 g active ingredient per hectare proved effective against leafhoppers and whiteflies, surpassing the standard treatment of phosphamidon 40% SL at 300 g active ingredient per hectare. Notably, the highest yields of brinjal fruits, ranging from 76.96 q/ha to 79.03 q/ha, were achieved with Flupyradifurone 200 SL at 150 g and 175 g active ingredient per hectare, while also demonstrating a safer profile towards coccinellid populations in the brinjal ecosystem (Wale *et al.,* 2017; Garg *et al.,* 2018).

Similar positive outcomes were reported in brinjal cultivation at Vidisha, Madhya Pradesh (Garg *et al.,* 2018). These findings underscore Flupyradifurone 200 SL as an effective and environmentally favourable option for pest management in various agricultural contexts.

The systemic and translaminar properties of Flupyradifurone 200 SL contribute to its efficacy by ensuring thorough coverage and penetration into plant tissues. This results in prolonged residual activity, offering extended protection against aphids beyond the initial application.

CONCLUSIONS

Based on the findings of this investigation, it is deduced that two foliar spray of Flupyradifurone 200 SL @ 0.1% with a 14-day interval effectively controls potato aphids while also yielding superior economic returns. This treatment regimen not only mitigates aphid infestations efficiently but also enhances profitability in potato cultivation.

FUTURE SCOPE

Future investigations could explore the long-term efficacy of the identified insecticides, such as Flupyradifurone and Pymetrozine, in managing aphid populations over multiple growing seasons. Additionally, research into the potential development of resistance in aphid populations to these compounds is crucial for sustainable pest management.

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Conflict of Interests. None.

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