

ECONOMICS AND RESURGENCE OF SUCKING INSECT PESTS OF POTATO AGAINST INSECTICIDES IN NORTHERN INDIA

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ABSTRACT: Field experiments were conducted to record the economics, incidence and resurgence effect of commonly used insecticides like imidacloprid, thiamethoxam and oxydemeton- methyl against whitefly, *Bemisia tabaci* (Gennadius) and leafhoppers *Amrasca biguttula biguttula* Isida on early planted potato (K. Pukhraj) crop during two consecutive years 2018 and 2019. The population of *B. tabaci* and *A. biguttula biuguttula* was active on potato crop throughout the crop growth. No resurgence of whitefly and leafhopper was noticed after the application of recommended and slightly higher doses of Imidacloprid 17.8 SL and Thiamethoxam 25% WG except its sub lethal doses. While Oxydemeton- Methyl 25 EC sprayed crop showed high degree of resurgence during both the years. Highest pooled mean tuber yield (21.81 t/ha) with maximum (14.91 %) increase in tuber yield was recorded from Thiamethoxam 25% WG @ 7g/10l four sprays treated plots. The sub lethal doses of imidacloprid and thiamethoxam and all the doses of oxydemeton- methyl were recorded negative and no increase in potato yield over control. Similarly, thiamethoxam 25% WG @ 7g/10l treated plot ranked first indicating the maximum return of Rs. 2.99 per rupee invested followed by imidacloprid 17.8 SL@6 ml/10l with Rs.2.09.

KEYWORDS: Potato, whiteflies, leafhoppers, insecticides, economics, resurgence

INTRODUCTION

The chaotic uses of unauthentic pesticides either low dosing or overdosing, improper applications, and repeated uses of the same group of insecticides lead to the development of resistance against most of the commonly used insecticides through natural selection pressure (Ghosal and Chatterjee, 2018). Similarly, pest resurgence is one of the important aspects related to indiscriminate use of these pesticides (Jayaraj and Regupathy, 1986). Beside the use of pesticides no other potent pest management option is still able to produce a quick knock down effect against insect vector population buildup on potato crop. Therefore, farmers are using different pesticides without proper care as per its appropriate doses in field conditions, resulting in resistance, resurgence and residues in the agro ecosystem. Potato (*Solanum tuberosum* Linn.) is an important cash

crop in India. It is cultivated under different eco-environmental conditions for local consumption and also available throughout the year (Rana and Pandey, 2007). The 53.02 million tonnes of potato is presently produced from 2.16 million ha area with an average productivity of 24.54 t/ha (Annual report, 2019). A complex of sucking pests used to infest the crop during crop growth. The leafhoppers and whitefly are most important among them due to sucking the sap directly from tender parts and transmitting important viral diseases, resulting in degeneration of potato. Whitefly is already established as an important vector and transmitting apical leaf curl virus in potato especially in Western India (Bhatnagar, 2007; Bhatnagar, 2008; Chandel *et al.* 2013 and Bhatnagar, 2013). Several insecticides belonging to different groups, mainly chlorinated hydrocarbons, organophosphate and pyrethroids have been recommended for their control but

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farmers generally complain after effectiveness of these insecticides against *whitefly* and *leafhoppers* on potato crop. It was perhaps due to continuous use of these insecticides resulting in the development of resistance and sometime resurgence against these conventional insecticides (Thakur *et al.*, 1991, Singh and Gupta, 1993). Insecticide resistance and resurgence of the most commonly used insecticides is a serious issue against whitefly and leafhopper on potato crop. Therefore, it is essential to study the economics and resurgence phenomena of whitefly and leafhoppers on potato crop while using the low, recommended and slightly higher doses of commonly recommended insecticides on potato crop under field conditions.

MATERIALS AND METHODS

Field experiments were conducted to record the resurgence effect of commonly used insecticides like imidacloprid, thiamethoxam and oxydemeton-methyl against whitefly, *Bemisia tabaci* (Gennadius) and leafhoppers *Amrasca biguttula biguttula* Isida on early planted potato crop at ICAR-Central Potato Research Institute Campus, Modipuram, Meerut (U.P.) during two consecutive years 2018 and 2019. The experiment was laid out in a randomized block design with plot size of 3 m × 3 m. Potato cultivar, K. Pukhraj was planted in 4th week of September during the respective years with three replications. All the agronomical package and practices recommended for the region were followed in raising a good crop. Ten treatments *viz.* T1- Imidacloprid 17.8 SL @ 2ml/10 l, T2- Imidacloprid 17.8 SL @ 4ml/10 l, T3- Imidacloprid 17.8 SL @ 6ml/10 l, T4- Thiamethoxam 25% WG @ 3g/10 l, T5- Thiamethoxam 25% WG @ 5g/10 l, T6- Thiamethoxam 25% WG @ 7g/10 l, T7- Oxydemeton-Methyl 25 EC @ 2ml/l, T8- Oxydemeton-Methyl 25 EC @ 3ml/l, T9- Oxydemeton-Methyl 25 EC @ 4ml/l

and T-10 control (without spray) were given when crop was 30, 45, 55 and 65 days old at 10 days interval.

The observations on the mean population buildup of whitefly and leafhoppers was recorded on 05 randomly selected plants covering upper, middle and lower leaves of each plant at before and 24hrs, 36 hrs and 48 hrs after each spray. For spraying the crop, Knapsack sprayer was used and crop was sprayed in the evening to preserve active natural enemies during both the years. After each spray each plot was covered with insect proof net (40 mesh) to restrict the movement of whitefly and leafhoppers from one plot to another. Percent resurgence was calculated using Henderson and Tilton (1955) formula after modification by Jayraj and Ragupathy (1986),

$$\% \text{ resurgence} = (T_s / C_s \times C_p / T_p - 1) \times 100$$

(Where, TF= infestation in the treated plot during first count, TS= infestation in the treated plot during subsequent count, CF= infestation in the untreated control plot during first count, CS= infestation in the untreated control plot during subsequent count). The yield data was recorded from net plot after removing haulm in the last week of December during both the years. The percent over size, seed size and small size tubers were recorded at the time of harvest in each plot. Benefit-Cost analysis was expressed in terms of Benefit: Cost ratio by using the following formula

$$\text{Cost benefit: ratio} = \frac{\text{Net return (Rs. ha}^{-1}\text{)}}{\text{Cost of treatment (Rs. ha}^{-1}\text{)}}$$

The data was further subjected to statistical analysis. Similarly, the % increase in tuber yield over unsprayed crop was calculated as follows-

$$\% \text{ increase in tuber yield} = \frac{\text{Tuber yield in sprayed plot} - \text{Tuber yield in unsprayed plot}}{\text{Tuber yield in unsprayed plot}} \times 100$$

RESULTS AND DISCUSSION

Population buildup of whitefly, *B. tabaci* and leafhoppers *A. biguttula biguttula* on potato

A day before the spray the mean population of whitefly and leafhoppers was

almost uniform across the experimental plots on early potato crop (21.67-26.67/ 5plants) and (2.33-4.33/ 5plants), respectively during 2019. Whitefly population differ significantly 24, 36 and 48 hrs after first, second and third sprays except fourth one on potato during 2019. The lowest number pooled mean of whitefly per 05 plant was recorded in the Imidacloprid 17.8 SL @ 6ml/10l treated plot (0.11-10.4 whiteflies/ 05 plant) followed by (0.89-7.9 /5 plants) in sprayed plot of Thiamethoxam 25% WG @ 5g/10 l (Fig 1). Similarly, the lowest number pooled mean of leafhopper per 05 plant was recorded in the Thiamethoxam 25% WG @ 7g/10 l treated plot (0.22-1.0 leafhopper/ 05 plant) followed by (0.11-2.0 /5 plants) in sprayed plot of Imidacloprid 17.8 SL @ 6ml/10 (Fig 3). A perusal of mean data revealed that less incidence of whitefly and leafhopper was recorded during 2018 as compared to 2019 on early potato crop. However, it showed almost the same trend as per the incidence in treated plots of insecticides. A day before the spray the mean population of whitefly and leafhoppers was almost uniform across

the experimental plots on early potato crop (16.37-18.52/ 5plants) and (2.67-4.07/ 5plants), respectively during 2018. Whitefly population differ significantly 24, 36 and 48 hrs after first, second and third sprays except fourth one on potato during 2018. The lowest number pooled mean of whitefly per 05 plant was recorded in the Thiamethoxam 25% WG @ 7g/10 l treated plot (0.11-4.9 whiteflies/ 05 plant) followed by 0.11-7.13 /5 plants) in sprayed plot of Imidacloprid 17.8 SL @ 6ml/10l (Fig 2). Similarly, the lowest number pooled mean of leafhopper per 05 plant was recorded in the Thiamethoxam 25% WG @ 7g/10 l treated plot (0.11-0.56 leafhopper/ 05 plant) followed by 0.11-1.67 /5 plants) in sprayed plot of Imidacloprid 17.8 SL @ 6ml/10 (Fig 4).

No significant difference of whitefly population was noticed among sprayed treatments after the fourth spray in the 50 days old crop. However, a significant difference was recorded against the leafhopper population during 2018 and 2019. Bhatnagar *et al.*, 2013 reported that sharp decrease in temperature after mid-November decreased whitefly and

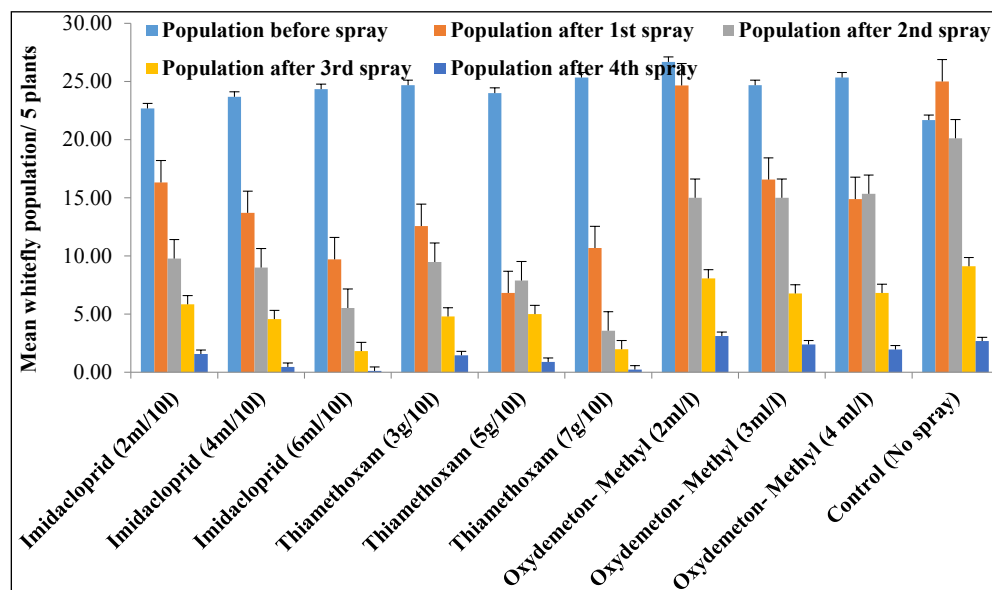


Fig. 1. Mean population buildup of whiteflies on potato after insecticide treatments during 2019

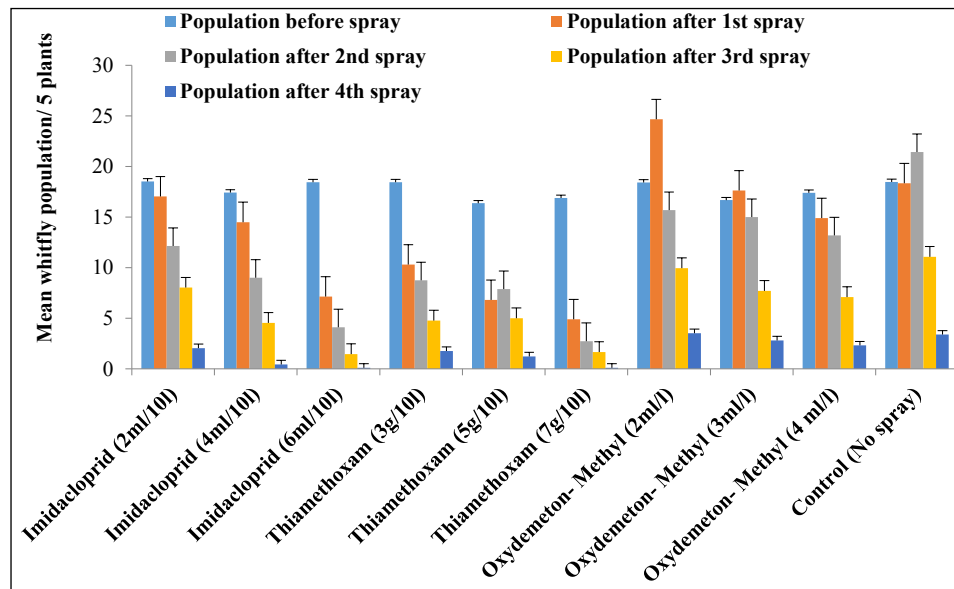


Fig.2. Mean population buildup of whiteflies on potato after insecticide treatments during 2018

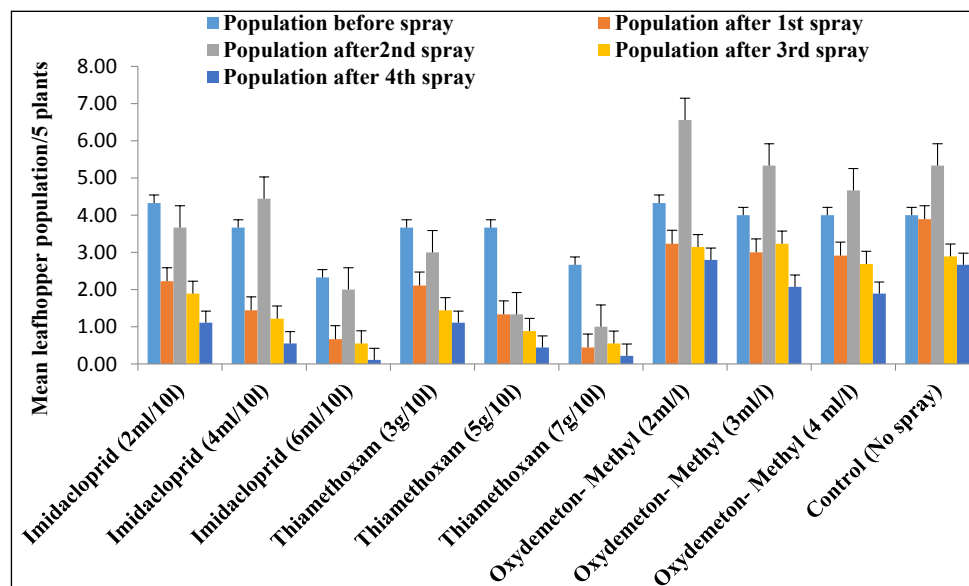


Fig.3. Mean population buildup of leafhoppers on potato after insecticide treatments during 2019

leafhoppers population drastically. Incidence of whitefly and leafhoppers population did not differ significantly in relation to plant protection treatments on potato crop after fourth spray. The earlier results indicate that, neonicotinoids provide excellent control of many sucking pests including leafhoppers and whitefly (Bhatnagar, 2007).

Our results are in agreement with Bhatnagar, 2007, who reported that neonicotinoids were effective against sap-feeding insect pests that are resistant to other classes of insecticides.

The population of *B. tabaci* and *A. biguttula biguttula* was active on potato crop

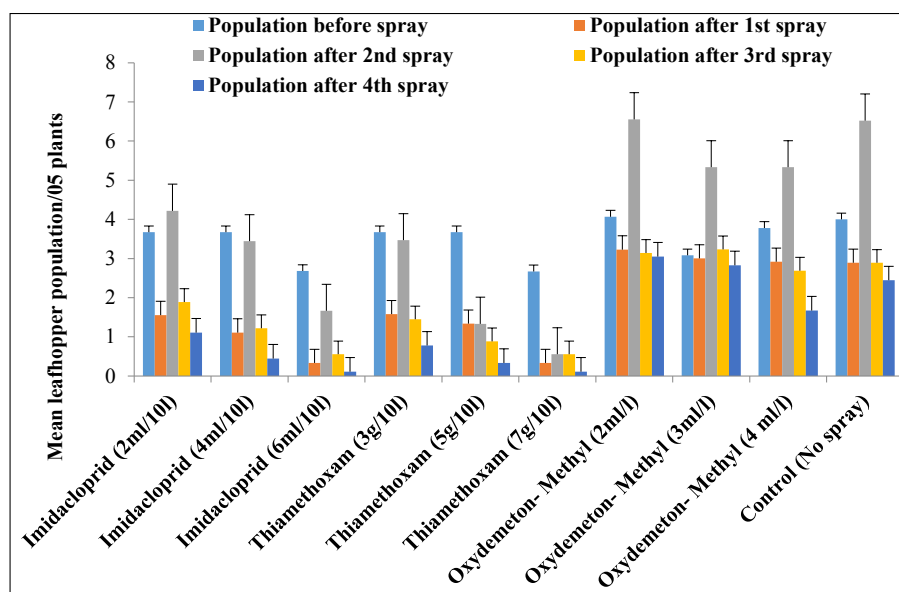


Fig.4. Mean population buildup of leafhoppers on potato after insecticide treatments during 2019

throughout the crop growth. The incidence of whitefly and leafhoppers population was resulted on early potato crop from residue population from natural host and weeds in the vicinity of the crop. However, the populations of whitefly and leafhoppers were indiscriminate on sprayed plots when crop was protected by four sprays of insecticides at low, higher and recommended doses against leafhoppers and whitefly. A perusal of whitefly incidence data revealed that whitefly has become a severe threat to potato crop by not only sucking the sap directly from the tender parts of potato plant and also transmitting important APCLV, resulting quick degeneration of potato seed (Bhatnagar, 2007 and Chandla *et al.*, 2001). Similarly, the incidence of leafhoppers has responsible for hopper burn especially in warmer region of the country.

Effect of commonly used insecticides on resurgence of whitefly in potato

Two years data of whitefly incidence revealed that moderate to high level of resurgence occurred at different doses of

Imidacloprid 17.8 SL, Thiamethoxam 25% WG and Oxydemeton-Methyl 25 EC from 1st spray to 4th spray of respective insecticide. Resurgence occurred as the calculated value of resurgence occurrence (%) was negative (Table-1 and 2). The percentage of resurgence was lowest in Thiamethoxam 25% WG @ 7g/10 l treated plot (-80.8%) after 1st spray followed by Thiamethoxam 25% WG @ 5g/10 l (-75.4%) and Imidacloprid 17.8 SL @ 6ml/10 (-65.4%), whereas highest in Oxydemeton-Methyl 25 EC @ 2ml/l (-19.8%) and Imidacloprid 17.8 SL @ 2ml/10 (-37.6%) during 2019. Similarly, the per cent resurgence of whitefly was varied from (-20.8%-61.2%), (-43.9%-79.9%) and (+6.41%- +13.8%) for Imidacloprid 17.8 SL, Thiamethoxam 25% WG and Oxydemeton-Methyl 25 EC, respectively during 2018. All the doses of Oxydemeton-Methyl 25 EC showed resurgence of whitefly population after first spray. After the second, third and fourth sprays the magnitude of resurgence of whitefly was reduced than first spraying which was ranged from (-34.8% to 84.8%), (-28.2% to 82.4%) and (-21.4% to -96.3%),

Table 1. Effect of insecticides on resurgence of whitefly (*Bemisia tabaci*) in potato during 2019.

Treatment	Dose ml/l	T _F	C _F	1 st spray			2 nd spray			3 rd spray			4 th spray		
				T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence
Imidacloprid 17.8 SL	2/10	22.6		16.3		-37.6	9.77		-53.6	5.82		-38.9	1.56		-43.9
Imidacloprid 17.8 SL	4/10	23.6		13.7		-49.9	9.00		-59.0	4.55		-54.3	0.44		-84.8
Imidacloprid 17.8 SL	6/10	24.3		9.7		-65.4	5.52		-75.5	1.80		-82.4	0.11		-96.3
Thiamethoxam 25% WG	3/10	24.6		12.5		-55.9	9.48		-58.6	4.78		-53.9	1.44		-52.4
Thiamethoxam 25% WG	5/10	24.0	21.7	5.6	25.0	-75.4	7.88	20.1	-64.7	3.87	9.11	-61.7	0.89	2.66	-69.8
Thiamethoxam 25% WG	7/10	25.3		10.6		-80.8	3.56		-84.8	1.96		-78.4	0.22		-92.8
Oxydemeton- Methyl 25 EC	2/1	26.6		24.6		-19.8	14.99		-39.4	8.06		-28.2	3.11		+94.9
Oxydemeton- Methyl 25 EC	3/1	24.6		16.5		-41.8	14.98		-43.3	6.76		-34.8	2.38		-21.4
Oxydemeton- Methyl 25 EC	4/1	25.3		14.9		-49.0	15.33		-34.8	6.80		-36.2	1.95		-26.7

T_F= infestation in the treated plot during first count, T_S= infestation in the treated plot during subsequent count, C_F= infestation in the untreated control plot during first count, C_S= infestation in the untreated control plot during subsequent count

Table 2. Effect of insecticides on resurgence of whitefly (*Bemisia tabaci*) in potato during 2018.

Treatment	Dose ml/l	T _F	C _F	1 st spray			2 nd spray			3 rd spray			4 th spray		
				T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence
Imidacloprid 17.8 SL	2/10	18.5		14.5		-20.8	12.14		-43.5	8.02		-27.7	2.04		-39.8
Imidacloprid 17.8 SL	4/10	17.4		10.8		-37.4	9.00		-55.5	4.55		-56.4	0.44		-86.2
Imidacloprid 17.8 SL	6/10	18.4		7.13		-61.2	4.10		-80.8	1.47		-86.7	0.11		-96.7
Thiamethoxam 25% WG	3/10	18.4		10.3		-43.9	8.76		-59.1	4.78		-56.8	1.77		-47.6
Thiamethoxam 25% WG	5/10	16.4	18.5	6.8	18.3	-58.3	7.89	21.4	-58.7	5.00	11.0	-49.4	1.22	3.38	-59.6
Thiamethoxam 25% WG	7/10	16.9		4.9		-70.9	2.74		-86.0	1.67		-83.5	0.11		-96.5
Oxydemeton- Methyl 25 EC	2/1	18.4		24.6		+34.4	15.69		-26.7	9.94		-10.2	3.52		+4.14
Oxydemeton- Methyl 25 EC	3/1	16.7		17.6		+6.41	14.99		-23.0	7.70		-23.5	2.82		-8.22
Oxydemeton- Methyl 25 EC	4/1	17.4		14.9		+13.8	13.19		-34.7	7.10		-32.0	2.31		-27.5

T_F= infestation in the treated plot during first count, T_S= infestation in the treated plot during subsequent count, C_F= infestation in the untreated control plot during first count, C_S= infestation in the untreated control plot during subsequent count

respectively after second, third and four spraying of insecticides during 2019. Similar trend of resurgence was recorded during 2018 (Table-1 and 2). It was noticed that when Oxydemeton- Methyl 25 EC were sprayed on potato crop the chance of whitefly resurgence increased along with sub lethal doses of Imidacloprid 17.8 SL and Thiamethoxam 25% WG. Positive values indicate the resurgence of the whitefly population.

Effect of commonly used insecticides on resurgence of leafhoppers in potato

The impact of commonly used insecticides on resurgence of leafhopper is presented in Table-3 and 4. The percentage of leafhopper resurgence values were also recorded negative in all the Imidacloprid 17.8 SL and Thiamethoxam 25% WG treated plots except Oxydemeton- Methyl 25 EC during both the year 2018 and 2019. The mean percentage of leafhopper resurgence after first spray was lowest in Thiamethoxam 25% WG @7 g/10l (-83.5%) followed by Imidacloprid 17.8 SL@6 ml/10l (-72.5%) whereas, highest in Oxydemeton- Methyl 25 EC@3 ml/l (-23.0%) and 2ml/l (-23.3%), respectively during 2019. It showed almost the same trend during 2018. All the doses of Oxydemeton -Methyl 25 EC showed resurgence of leafhoppers during the years 2018 and 2019. After the second spray the magnitude of leafhopper resurgence was varied from -37.2% to -69.0% (Imidacloprid 17.8 SL) and -39.2% to -72.0% (Thiamethoxam 25% WG) during the year 2019, while it was -30.0% to -61.8% (Imidacloprid 17.8 SL) and -42.5% to -87.2% (Thiamethoxam 25% WG) during the year 2018. After the third spray, the magnitude of leafhopper resurgence showed almost the same trend as after the second spray. The values of resurgence was varied from -61.6% to -92.9% (Imidacloprid 17.8 SL) and -54.9% to -87.7% (Thiamethoxam 25% WG) during the year 2019, while it was

Table 3. Effect of insecticides on resurgence of leafhoppers (*Anrasca biguttula biguttula*) in potato during 2019.

Treatment	Dose ml/l	T _F	C _F	1 st spray			2 nd spray			3 rd spray			4 th spray		
				T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence
Imidacloprid 17.8 SL	2/10	4.33		2.22		-47.3	3.66		-37.9	1.89		-39.8	1.11		-61.6
Imidacloprid 17.8 SL	4/10	3.67		1.44		-59.7	3.00		-39.2	1.22		-54.4	0.55		-77.6
Imidacloprid 17.8 SL	6/10	2.33		0.66		-72.5	1.00		-69.0	0.55		-67.5	0.11		-92.9
Thiamethoxam 25% WG	3/10	3.67		2.11		-41.1	3.00		-39.2	1.44		-46.2	1.11		-54.9
Thiamethoxam 25% WG	5/10	3.67	4.00	1.33	3.89	-63.3	1.33	5.33	-73.0	0.88	2.89	-67.1	0.44	2.66	-82.1
Thiamethoxam 25% WG	7/10	2.67		0.44		-83.5	1.00		-72.0	0.55		-71.6	0.22		-87.7
Oxydemeton- Methyl 25 EC	2/1	4.33		3.23		-23.3	6.55		+13.0	3.14		-0.04	2.80		-3.15
Oxydemeton- Methyl 25 EC	3/1	4.00		3.00		-23.0	5.57		+14.5	3.23		+11.7	2.07		-22.2
Oxydemeton- Methyl 25 EC	4/1	4.00		2.91		-26.0	4.66		-12.6	2.69		-6.92	1.89		-28.9

T_F= infestation in the treated plot during first count, T_S= infestation in the treated plot during subsequent count, C_F= infestation in the untreated control plot during first count, C_S= infestation in the untreated control plot during subsequent count

Table 4. Effect of insecticides on resurgence of leafhoppers (*Amrasca biguttula biguttula*) in potato during 2018.

Treatment	Dose ml/l	T _F	C _F	1 st spray			2 nd spray			3 rd spray			4 th spray		
				T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence	T _S	C _S	% resurgence
Imidacloprid 17.8 SL	2/10	3.67	4.00	1.56	4.22	-41.8	4.22	6.52	-30.0	1.89	2.89	-29.4	1.11	2.44	-50.8
Imidacloprid 17.8 SL	4/10	3.67	4.00	1.11	3.44	-58.1	3.44	6.52	-43.0	1.22	2.89	-54.4	0.44	2.44	-80.5
Imidacloprid 17.8 SL	6/10	2.68	4.00	0.33	1.67	-82.9	1.67	6.52	-61.8	0.56	2.89	-71.1	0.11	2.44	-93.2
Thiamethoxam 25% WG	3/10	3.67	4.00	1.58	3.47	-40.5	3.47	6.52	-42.5	1.45	2.89	-45.8	0.78	2.44	-65.4
Thiamethoxam 25% WG	5/10	3.67	4.00	1.34	2.89	-49.9	1.33	6.52	-77.9	0.89	2.89	-66.7	0.33	2.44	-85.4
Thiamethoxam 25% WG	7/10	2.67	4.00	0.33	0.56	-82.9	0.56	6.52	-87.2	0.55	2.89	-71.6	0.11	2.44	-93.2
Oxydemeton- Methyl 25 EC	2/1	4.07	3.00	3.23	6.56	+9.09	6.56	5.33	-1.39	3.14	3.24	+6.47	3.05	2.83	+22.5
Oxydemeton- Methyl 25 EC	3/1	3.08	3.00	3.00	5.33	+33.8	5.33	5.33	+5.45	3.24	2.83	+20.0	2.83	2.83	+49.6
Oxydemeton- Methyl 25 EC	4/1	3.78	2.92	2.92	5.33	+6.87	5.33	5.33	+14.2	2.69	2.69	-2.26	1.67	1.67	-28.1

T_F= infestation in the treated plot during first count, T_S= infestation in the treated plot during subsequent count, C_F= infestation in the untreated control plot during first count, C_S= infestation in the untreated control plot during subsequent count

-50.8% to -93.2% (Imidacloprid 17.8 SL) and -65.4% to -93.2% (Thiamethoxam 25% WG) during the year 2018 after fourth spray. It shows that no resurgence occurred in the recommended and slightly higher doses of Imidacloprid 17.8 SL and Thiamethoxam 25% WG. It is prominent from the experimental result depicted above that the Imidacloprid 17.8 SL and Thiamethoxam 25% WG induced no resurgence at recommended and slightly higher doses against whitefly and leafhoppers on potato crop but Oxydemeton-Methyl 25 EC was recorded high degree of resurgence against both the pests. However, Imidacloprid 17.8 SL @2ml/10l showed resurgence of whiteflies and leafhoppers in both the years. All other doses of Imidacloprid 17.8 SL and Thiamethoxam 25% WG showed moderate to maximum toxicity towards whitefly and leafhopper and prevented resurgence of both the insects. Although we are well acquainted that imidacloprid is a key insecticide, universally used for the management of sucking pests on potato but extensive and repeated use before imidacloprid for suppressing whitefly, aphids and leafhoppers has placed a heavy selection pressure on target insect, which may cause of reduced efficacy and resurgence of population. Besides that sub lethal exposure to imidacloprid and thiamethoxam may be stimulated whitefly and leafhopper population growth by increasing fecundity or shortening the development period. This phenomenon also might be attributed to diverse climate, cropping system and introduction of new potato varieties or may be wide spread use of pesticide related factors. The low efficacy of imidacloprid against adult whitefly and leafhopper was reported to be due to emergence of biotypes (Pirmoradi *et al.*, 2001). From our present findings it can be concluded that repeated use of imidacloprid and thiamethoxam should

be checked immediately and never to use its sub-lethal doses.

Per cent different size of tubers, tuber yield and it's economics

Pooled per-cent mean numbers of different size tubers did not differ statistically among the different doses of insecticide treated plots (Table 5). Highest pooled mean tuber yield (21.81 t/ha) was recorded from Thiamethoxam 25% WG @ 7g/10l four sprays treated potato plot followed by sprayed plots of Imidacloprid 17.8 SL@6 ml/10l (20.60 t/ha) and Imidacloprid 17.8 SL@4 ml/10l (20.35 t/ha). The sub lethal doses of imidacloprid and thiamethoxam and all the doses of Oxydemeton- Methyl were recorded negative and no increase in potato yield over control. However, maximum (14.91 %) increase in tuber yield was recorded in thiamethoxam25% WG @ 7g/10l treated plot followed by Imidacloprid 17.8 SL@6 ml/10l (8.53%) (Table5). By working out cost benefit ratio it is evident that thiamethoxam25% WG @ 7g/10l treated plot ranked first indicating the maximum return of Rs. 2.99 per rupee invested followed by Imidacloprid 17.8 SL@6 ml/10l with Rs.2.09. Jaykar *et al.* (2019) also reported that K. Pukhraj, K. Khyati, K. Anand and K.Garima recorded the highest tuber yield under protected conditions. Further, Bhatnagar (2013) confirmed that soil application of insecticides and two to three sprays of insecticides were required for complete protection of potato crop against insect pests under field conditions.

CONCLUSION

Three sprays of insecticides may be incorporated in the spray schedule against sucking pests especially whiteflies and leafhoppers for getting potential yield of potato. The use of pesticides from the emergence of potato crop to 55 days

Table 5. Effects of insecticides treatments on yield, % seed grade and C: B ratio of early potato (K. Pukhraj) crop (pooled data of 2018 & 2019)

Insecticides treatments	Dose ml/l	% Grade tubers			Mean tuber yield (t/ha)	Economics of treatments					Benefit: Cost Ratio (1/2)
		Over size	Seed size	Small size		% increase in yield over control	increase in yield over control (t/ha)	*Cost of increase yield potato (Rs.)	**Cost of plant protection (Rs.)	Net profit (Rs.) (2)	
Imidacloprid 17.8 SL	2/10	7.86	38.32	53.07	18.84	0.73	0.14	1120	3760	-2640	-
Imidacloprid 17.8 SL	4/10	9.12	40.47	50.35	20.35	7.21	1.37	10960	3960	7000	1:1.76
Imidacloprid 17.8 SL	6/10	5.50	43.50	51.00	20.60	8.53	1.62	12960	4190	8770	1:2.09
Thiamethoxam 25% WG	3/10	5.87	40.87	53.25	18.63	0.0	-0.35	-	4760	-	-
Thiamethoxam 25% WG	5/10	6.44	47.86	45.69	20.33	7.11	1.35	10800	4960	5840	1:1.17
Thiamethoxam 25% WG	7/10	8.58	42.85	48.56	21.81	14.91	2.83	22640	5672	16968	1:2.99
Oxydemeton- Methyl 25 EC	2/1	6.17	37.78	56.03	17.86	0.0	-1.12	-	3242	-	-
Oxydemeton- Methyl 25 EC	3/1	6.48	43.82	49.78	18.27	0.0	-0.71	-	3440	-	-
Oxydemeton- Methyl 25 EC	4/1	7.91	42.62	49.45	18.49	0.0	-0.49	-	3682	-	-
Control (No spray)	-	8.20	41.87	50.62	18.98	-	-	-	-	-	-
SEM _{±1}	-	1.91	4.16	3.46	0.75	-	-	-	-	-	-
CD (p=0.05)	-	NS	NS	NS	2.26	-	-	-	-	-	-

Date of 1st spraying 27.10., 2nd 04.11., 3rd 14.11 and 4th 24.11. * Cost of potato Rs. 8000/ t ** (Cost of plant protection- Labor+ spray product +Machine)

old effectively reduced the whitefly and leafhopper population and significantly increased tuber yield. It can be concluded that, imidacloprid and thiamethoxam are the preferred insecticides with appropriate doses having less toxicity to the mammals and can be used to control sucking insect pests in potato IPM programs.

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CONFLICTS OF INTEREST:

The authors confirm that this manuscript has no conflicts of interest

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