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Bio-efficacy evaluation of insecticides against aphids infesting potato

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ABSTRACT

A study was carried out at the AICRP potato experimental plots at OUAT, Bhubaneswar during the rabi seasons of 2018–19 and 2019–20 to assess the effectiveness of pesticides against potato aphid infestations and their impact on natural enemies. For the experiment, the untreated control, imidacloprid 17.8SL @ 0.4 ml l^{-1} of water seed treatment followed by sprays of imidacloprid 17.8SL @150ml ha^{-1} and thiamethoxam 25WG @100 g ha^{-1} at 30 and 40 days after planting (DAP), foliar spray of diafenthiuron 50WP @700gha^{-1} once at 30 DAP, spray of diafenthiuron 50 at 30 and 40 DAP, foliar spray of castor oil @250 ml ha^{-1} , foliar spray of diafenthiuron 50WP @ 700g ha^{-1} mixed with castor oil @250ml ha^{-1}at 30 DAP, and the same along with diafenthiuron 50WP @700g ha^{-1} at 40 DAP were considered. The treatment consisting spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40DAP proved to be the most effective, with highest reduction in aphids. The diafenthiuron-containing treatments were proven comparatively safer for coccinellid predators.

Keywords: Aphid, castor oil, coccinellid predators, diafenthiuron, *Solanum tuberosum* L.

The potato, *Solanum tuberosum* L., is one of the most popular food crops of the world. It may thrive in both temperate and tropical climates. It is a widely referred horticultural crop known as the "King of Vegetables." It has a lot of uses and is quite nutritious. In terms of potato production and area, India ranks the second in the world (FAO STAT, 2017). Potatoes are cultivated in every state of India except Kerala. In India, a wide range of insect pests attack potatoes. Soil pests, foliage feeders, sap feeders and storage pests are among the different types of pests. As vegetatively propagated tubers are grown, some pathogens and pests are easily carried causing pest problems (Chandel *et al.* 2007). Potato plants are damaged by feeding of insects on leaves, resulting in reduction of photosynthetic area, attacks on stems and inhibiting nutrient transport.

Various sucking pests damage the potato crop and aphids are the major one. In India, the peach potato aphid (*Myzus persicae* Sulzer), potato root aphid (*Rhopalosiphum rufiabdominalis* Sasaki), cotton aphid (*Aphis gossypii* Glover), bean aphid (*Aphis fabae* Scopoli) and tuber aphid (*Rhopalosiphoninus latysiphon* Davidson) are the most common aphid species (Joshi *et al*. 2013).Out of different aphid species, *M. persicae* is the most common pest on potatoes (Chandel *et al*., 2008). The adult aphids and nymphs usually attached to the lower side of the leaves and young tender parts of the plant. Aphids feed on the sap of potato plants, inflicting damage and transmitting a number of important potato viruses like potato virus A, potato virus Y, potato virus M, potato apical leaf curl virus (PALCV), potato leaf roll virus (PLRV) and potato acute mosaic virus. The role of aphid as virus vector is a major problem. Aphids excrete honeydew, which is accumulated on the plant and offers a favourable environment for sooty moulds to thrive (Chandel *et al.*, 2008).

Aphids are serious pests of potato crop. For this, synthetic pesticides are mainly used to protect against aphids, but these pesticides have adverse effects on non-target species, including humans. Hence, it is critical to assess the effectiveness of new generation pesticides with selective toxicity against potato aphids. Insecticides with selective toxicity to target pests while remaining safer to the beneficial insects are urgently needed. In addition to these characteristics, insecticides should be more user-friendly and environment friendly. In order to evaluate the efficacy of insecticides against aphids and their influence on beneficial insects, a study was conducted in potato.

MATERIALS AND METHODS

The trial was conducted at experimental plots of AICRP on potato during both *rabi* seasons of 2018-19 and 2019-20 in association with RRTTS (Regional Research and Technology Transfer Station),

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Bhubaneswar. The research site was located at 20°27'43"N and 85°78'88"E and at a height of 25.9 meters above MSL (mean sea level). The goal of the study was to see how effective the insecticides are against aphids infesting potato and how do they affect beneficial insect populations. 'Kufri Jyoti' potato variety was considered for the experiment. The trial was carried out in a Randomized Block Design (RBD) in three replications and with seven treatments. The treatments constituted; untreated control (T_1), The standard chemical treatment included seed (tuber) treatment with imidacloprid 17.8SL @0.4 ml l^{-1} of water before planting along with foliar spray of imidacloprid 17.8SL @150ml ha^{-1} at 30 DAP (days after planting) followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP (T_2), once foliar spray of diafenthiuron 50 WP @700g ha^{-1} at 30DAP (T_3), foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP (T_4), once foliar spray of castor oil @250ml ha^{-1} at 30DAP (T_5), once foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP (T_6), foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP (T_7).

The potato tubers were treated with imidacloprid 17.8 SL @0.4ml l^{-1} of water for 30 minutes before planting in the T_2 plots. In rest plots, untreated tubers were sown. At 30 and 40 DAP; the insecticide and the insecticide+ castor oil were sprayed as per schedule. Observations were taken at 1 DBS (one day before spray), 3DAS (three days after spray) and 7 DAS (seven days after spray). At an interval of 7 days, the number of aphids per leaf, the percentage of viral incidence in each plot and the population of predatory coccinellids were recorded.

At maturity each treatment plot's potatoes were harvested separately, and the weight of marketable tubers was calculated in tonnes $hectare^{-1}$for the economics study.The data was analyzed using OPSTAT software (https: //www.google. com/search? q=opstat +home+page, 2020).

RESULTS AND DISCUSSION

The population of aphids recorded during the *rabi*, 2018-19 presented in Table 1.1 revealed that the treatment 'foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP had the minimum of 0.13 aphid $leaf^{-1}$ to zero aphid population. This was preceded by the treatment constituting foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP with an aphid population of 0.33 to 0.20 aphids $leaf^{-1}$. The standard chemical treatment Seed treatment with imidacloprid 17.8SL @0.4 ml l^{-1} before planting along with foliar spray of imidacloprid 17.8SL @150ml ha^{-1} at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40 DAP had 0.64 to 0.40 aphids $leaf^{-1}$. The results of 2019-20 illustrated in Table 1.2 indicates that the treatment containing foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP was superior in controlling aphid population (0.42 aphids $leaf^{-1}$ to 0.02 aphids $leaf^{-1}$). The treatment foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP was the second-best treatment (0.80 aphids $leaf^{-1}$ to 0.24 aphids $leaf^{-1}$). The standard chemical treatment seed treatment with imidacloprid 17.8SL @0.4 ml l^{-1} before planting along with foliar spray of imidacloprid 17.8SL @150ml ha^{-1} at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP' recorded 0.98 aphids $leaf^{-1}$ to 0.44 aphids' $leaf^{-1}$. The pooled mean result of *rabi*, 2018-19 and 2019-20 presented in Table 1.3 depicted similar results where the treatment foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP was found to be superior with least count of aphids (0.48 aphids $leaf^{-1}$ to 0.01 aphids $leaf^{-1}$) and 90% reduction in aphids over untreated control followed by the treatment foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP (0.70 aphids $leaf^{-1}$ to 0.22 aphids $leaf^{-1}$) with 78% reduction in aphids over untreated control. The standard chemical treatment seed treatment with imidacloprid 17.8SL @0.4 ml l^{-1} before planting along with foliar spray of imidacloprid 17.8SL @150ml ha^{-1} at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP recorded 0.83 aphids $leaf^{-1}$ to 0.42 aphids $leaf^{-1}$ with 68% reduction in aphids over untreated control.

These findings of a synergistic impact of mixture of castor oil with diafenthiuron against aphid in potato corroborated with the report of Bajya *et al.* (2016), who found that diafenthiuron 47.8SC @286.8g a.i. ha^{-1} was showing good results in limiting the aphid counts. This also agrees with the reports of Hamalepure *et al.* (2016), they found, sunflower oil and imidacloprid 200SL have a synergistic impact against aphids. The current study, which indicates that imidacloprid and thiamethoxam exhibit population reducing potential against aphids, is similar to that of studies of Boiteau *et al.*(1997), who claimed that imidacloprid at 50 g a.i. ha^{-1} reduced aphid

Table 1.1: Population of aphids in potato during *rabi*, 2018-19

	Treatment details	Aphids leaf^{-1} (*rabi*, 2018-19)					
		First spray			Second spray		
		1 DBS	3 DAS	7 DAS	1 DBS	3 DAS	7 DAS
T_1	Untreated Control	0.94 (1.39)	1.09 (1.45)	1.96 (1.72)	2.07 (1.75)	2.51 (1.87)	2.67 (1.92)
T_2	ST + foliar spray of imidacloprid 17.8SL @150ml ha-1 at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP	0.98 (1.41)	0.67 (1.29)	0.64 (1.28)	0.67 (1.29)	0.44 (1.20)	0.40 (1.18)
T_3	Once foliar spray of diafenthiuron 50 WP @700g ha^{-1} at 30DAP	1.02 (1.42)	0.62 (1.27)	0.40 (1.18)	0.47 (1.21)	0.60 (1.27)	0.71 (1.31)
T_4	Foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP	0.98 (1.41)	0.60 (1.27)	0.33 (1.15)	0.44 (1.20)	0.27 (1.12)	0.20 (1.09)
T_5	Once foliar spray of castor oil @250ml ha-1 at 30DAP	0.96 (1.40)	0.87 (1.37)	1.47 (1.57)	1.82 (1.68)	2.47 (1.86)	2.64 (1.91)
T_6	Once foliar spray of diafenthiuron 50WP @700g ha-1 mixed with castor oil @250ml ha^{-1} at 30DAP	1.00 (1.41)	0.42 (1.19)	0.18 (1.08)	0.24 (1.11)	0.40 (1.18)	0.69 (1.30)
T_7	Foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP	0.98 (1.41)	0.40 (1.18)	0.13 (1.06)	0.22 (1.10)	0.09 (1.04)	0.00 (1.00)
SE(m)±		**0.049**	**0.018**	**0.023**	**0.023**	**0.021**	**0.025**
CD(P=0.05)		**NS**	**0.06**	**0.07**	**0.07**	**0.07**	**0.08**

Figures in the parentheses are √(x+1) transformed values of original data.
DAS: Days After Spraying DBS: Days Before Spraying NS: Non-significant
ST: seed (tuber) treatment with imidacloprid 17.8 SL @ 0.4ml litre^{-1} of water

counts by 50 to 75 percent. Similarly, Khan *et al*. (2011) found that imidacloprid 1.6F and thiamethoxam 25WG caused 74.92% and 67.79% aphid reduction. The efficiency of imidacloprid and thiamethoxam against the aphid, according to El-Naggar and Zidan (2013), is consistent with the current experimental results.

The data from both seasons, *rabi* 2018-19 and *rabi* 2019-20, show that plots treated with diafenthiuron were comparatively safer to coccinellid predators than plots treated with imidacloprid or thiamethoxam (Table 2).The plots treated with either diafenthiuron 50 WP @ 700 g ha^{-1} alone or mixed with castor oil@ 250 ml ha^{-1} once at 30 DAP had 69% reduction over control. The treated plots with either diafenthiuron 50WP @700 g ha^{-1} alone or mixed with castor oil @250 ml ha^{-1} twice at 30 and 40DAP had up to 81% mortality of predatory coccinellids as compared to 93% mortality in treated plots with standard chemicals like imidacloprid and thiamethoxam. The castor oil @250ml ha^{-1} treatment plots exhibited the highest number of predatory coccinellid population (0.70coccinellids leaf^{-1} to 2.08coccinellids leaf^{-1}) and were statistically equivalent

Table 1.2: Population of aphids in potato during *rabi*, 2019-20

Treatment details		Number of aphids leaf^{-1}					
		First spray			Second spray		
		1 DBS	3 DAS	7 DAS	1 DBS	3 DAS	7 DAS
T_1	Untreated Control	1.22 (1.49)	1.53 (1.59)	1.78 (1.67)	1.81 (1.68)	2.24 (1.80)	2.58 (1.89)
T_2	ST + foliar spray of imidacloprid 17.8SL @150ml ha-1 at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP	1.29 (1.51)	0.98 (1.41)	0.84 (1.36)	0.87 (1.37)	0.67 (1.29)	0.44 (1.20)
T_3	Once foliar spray of diafenthiuron 50 WP @700g ha^{-1} at 30DAP	1.18 (1.47)	0.82 (1.35)	0.69 (1.30)	0.71 (1.31)	0.82 (1.35)	1.00 (1.41)
T_4	Foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP	1.20 (1.48)	0.80 (1.34)	0.71 (1.31)	0.73 (1.32)	0.42 (1.19)	0.24 (1.11)
T_5	Once foliar spray of castor oil @250ml ha^{-1} at 30DAP	1.29 (1.51)	1.04 (1.43)	1.53 (1.59)	1.65 (1.63)	2.22 (1.79)	2.55 (1.89)
T_6	Once foliar spray of diafenthiuron 50WP @700g ha-1 mixed with castor oil @250ml ha^{-1} at 30DAP	1.15 (1.47)	0.58 (1.26)	0.47 (1.21)	0.49 (1.22)	0.71 (1.31)	0.80 (1.34)
T_7	Foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP	1.22 (1.49)	0.56 (1.25)	0.42 (1.19)	0.47 (1.21)	0.20 (1.10)	0.02 (1.01)
SEm(±)		**0.045**	**0.023**	**0.025**	**0.020**	**0.025**	**0.018**
CD(P=0.05)		**NS**	**0.07**	**0.08**	**0.06**	**0.08**	**0.06**

Figures in the parentheses are "(x+1) transformed values of original data
DAS: Days After Spraying; DBS: Days Before Spraying NS: Non-significant
ST: seed (tuber) treatment with imidacloprid 17.8 SL @ 0.4ml litre^{-1} of water

to the untreated control plot (0.74coccinellids leaf^{-1} to 1.97coccinellids leaf^{-1}).

The current findings are in line with those of Stanley *et al.*(2016), who reported that diafenthiuron 47.8 SC was observed to be slightly harmful to coccinellid grubs which is consistent with the current findings.

Table 2 shows the efficiency of pesticides against viral infections in potato plants revealing the treatments containing foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP, foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP and seed treatment with imidacloprid 17.8SL @0.4 ml l^{-1} before planting along with foliar spray of imidacloprid 17.8SL @150ml ha^{-1} at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP were statistically equivalent where 60-65% reduction in viral incidence. The current findings are consistent with those of Hussain *et al.*(2016), who reported that imidacloprid and diafenthiuron were effective against leaf curl virus disease of tomato. Pawinska and Turska (1995) confirmed the current finding, concluding that imidacloprid was remarkably efficient against aphids and potato leaf roll virus.

Table 1.3: The pooled mean aphid population of *rabi*, 2018-19 and *rabi*, 2019-20

		Number of aphids leaf^{-1}				Percent reduction over untreated control
	Treatment details	First spray		Second spray		
		3 DAS	7 DAS	3 DAS	7 DAS	
T_1	Untreated Control	1.31 (1.59)	1.87 (1.67)	2.38 (1.80)	2.63 (1.89)	
T_2	ST + foliar spray of imidacloprid 17.8SL @150ml ha-1 at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP	0.83 (1.41)	0.74 (1.36)	0.56 (1.29)	0.42 (1.20)	68
T_3	Once foliar spray of diafenthiuron 50 WP @700g ha^{-1} at 30DAP	0.72 (1.35)	0.55 (1.30)	0.71 (1.35)	0.86 (1.41)	65
T_4	Foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP	0.70 (1.34)	0.52 (1.31)	0.35 (1.19)	0.22 (1.11)	78
T_5	Once foliar spray of castor oil @250ml ha-1 at 30DAP	0.96 (1.43)	1.50 (1.59)	2.35 (1.79)	2.60 (1.89)	9
T_6	Once foliar spray of diafenthiuron 50WP @700g ha-1 mixed with castor oil @250ml ha^{-1} at 30DAP	0.50 (1.26)	0.33 (1.21)	0.56 (1.31)	0.75 (1.34)	73
T_7	Foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP	0.48 (1.25)	0.28 (1.19)	0.15 (1.10)	0.01 (1.01)	90
SEm(±)		**0.015**	**0.017**	**0.016**	**0.016**	
CD(P=0.05)		**0.04**	**0.05**	**0.05**	**0.05**	

Figures in the parentheses are "(x+1) transformed values of original data
DAS: Days After Spraying; DBS: Days Before Spraying NS: Non-significant
ST: seed (tuber) treatment with imidacloprid 17.8 SL @ 0.4ml litre^{-1} of water

From Table 3 it is concluded that the treated plots with foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP achieved maximum potato tuber yield (10.81q ha^{-1} and 9.51q ha^{-1}) during both the seasons and the pooled mean tuber yield (10.16 t ha^{-1}) with 43% yield improvement over untreated control and benefit cost ratio (1.62). The second highest potato tuber yield (9.19t ha^{-1}) with 29% yield improvement and benefit cost ratio (1.52) was obtained from the treated plots with standard chemicals treatment comprising seed treatment with imidacloprid 17.8SL @0.4 ml l^{-1} before planting along with foliar spray of imidacloprid 17.8SL @150ml ha^{-1} at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40 DAP.

From the investigation, this may be concluded that among all the treatments tried, the treatment constituting foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP was the most effective treatment against the aphids' infesting potato with 90% reduction over control achieving maximum potato tuber yield (10.16 t ha^{-1}) with 43% yield improvement over untreated control. In economic term, it had highest net income (Rs78,000 ha^{-1}) and the benefit cost ratio (1.62). Diafenthiuron was observed to be comparatively safer to the coccinellid predators than the standard chemicals like imidacloprid and thiamethoxam.

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Table 2: Pooled mean of predatory coccinellids and viral incidence during *rabi*, 2018-19 and *rabi*, 2019-20

	Treatment details	Pooled mean predatory coccinellids leaf^{-1}				Percent reduction over untreated control	Viral incidence (%)			Percent reduction over untreated control
		First spray		Second spray			*rabi*, 2018-2019	*rabi*, 2019-2020	Pooled mean	
		3 DAS	7 DAS	3 DAS	7 DAS					
T_1	Untreated Control	0.74 (1.36)	1.11 (1.45)	1.61 (1.62)	1.97 (1.71)		23.33	26.67	25	
T_2	ST + foliar spray of imidacloprid 17.8SL @150ml ha-1 at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP	0.20 (1.12)	0.10 (1.07)	0.07 (1.04)	0.01 (1.01)	93	8.00	12.00	10	60
T_3	Once foliar spray of diafenthiuron 50 WP @700g ha^{-1} at 30DAP	0.46 (1.20)	0.24 (1.13)	0.40 (1.21)	0.57 (1.27)	69	15.33	17.33	16.33	35
T_4	Foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP	0.45 (1.21)	0.24 (1.12)	0.19 (1.10)	0.12 (1.07)	81	6.67	10.67	8.67	65
T_5	Once foliar spray of castor oil @250ml ha-1 at 30DAP	0.70 (1.32)	1.04 (1.41)	1.70 (1.65)	2.08 (1.75)	-	24.67	26.00	25.33	-
T_6	Once foliar spray of diafenthiuron 50WP @700g ha-1 mixed with castor oil @250ml ha^{-1} at 30DAP	0.44 (1.18)	0.24 (1.15)	0.44 (1.21)	0.52 (1.23)	69	16.00	18.67	17.33	30
T_7	Foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP	0.48 (1.20)	0.28 (1.17)	0.16 (1.11)	0.08 (1.05)	81	6.00	10.00	8	68
SEm(±)		**0.011**	**0.009**	**0.010**	**0.009**		**1.693**	**1.942**	**1.251**	
CD(P=0.05)		**0.03**	**0.03**	**0.03**	**0.03**		**5.27**	**6.05**	**3.66**	

Figures in the parentheses are √(x+1) transformed values of original data; DAS: Days after Spraying DBS: Days before ST: seed (tuber) treatment

Table 3: Yield and economics of marketable potato

Treatment details		Marketable potato tuber yield and economics							
		***Rabi*, 2018-19 yield (t ha^{-1})**	***Rabi*, 2019-20 yield (t ha^{-1})**	**Pooled mean yield (t ha^{-1})**	**Percent yield improvement over control**	**Gross income (Rs ha^{-1})**	**Cost of cultivation (Rs. ha^{-1})**	**Net income (Rs. ha^{-1})**	**Benefit cost ratio**
T_1	Untreated Control	8.07	6.12	7.10		1,42,000	1,20,000	22,000	1.18
T_2	ST + foliar spray of imidacloprid 17.8SL @150ml ha-1 at 30 DAP followed by thiamethoxam 25WG @100g ha^{-1} at 40DAP	10.13	8.25	9.19	29	1,83,800	1,20,550	63,250	1.52
T_3	Once foliar spray of diafenthiuron 50 WP @700g ha^{-1} at 30DAP	8.97	6.98	7.98	12	1,59,600	1,22,500	37,100	1.30
T_4	Foliar spray of diafenthiuron 50WP @700g ha^{-1} at 30DAP and 40DAP	9.71	8.13	8.92	25	1,78,400	1,25,000	53,400	1.43
T_5	Once foliar spray of castor oil @250ml ha-1 at 30DAP	8.64	6.10	7,37	4	1,47,400	1,20,200	27,200	1.23
T_6	Once foliar spray of diafenthiuron 50WP @700g ha-1 mixed with castor oil @250ml ha^{-1} at 30DAP	9.07	7.12	8.10	14	1,62,000	1,22,700	39,300	1.32
T_7	Foliar spray of diafenthiuron 50WP @700g ha^{-1} mixed with castor oil @250ml ha^{-1} at 30DAP followed by diafenthiuron 50WP @700g ha^{-1} at 40 DAP	10.81	9.51	10.16	43	2,03,200	1,25,200	78,000	1.62
SE(m)±		**0.118**	**0.118**	**0.114**					
CD(P=0.05)		**0.36**	**0.37**	**0.24**					

ST: Imidacloprid 17.8 SL seed(tuber) treatment @ 0.4ml litre^{-1} water

The gross income was calculated on the basis of average wholesale price @ Rs. 20000 t^{-1}

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