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Evaluation of Novel Insecticides against Tobacco Caterpillar *Spodoptera litura* and Castor Semilooper *Achaea janata* of Castor

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Authors' contributions

This work was carried out in collaboration among all authors. Author KB conducted the experiment and wrote the manuscript. Author CMSV designed the research and helped in statistical analysis of data. Author Radhika provided the seed material for conducting the experiment. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to evaluate the efficacy of ten insecticides viz., spinetoram 11.7 SC @ 0.5 ml l-1, cyantraniliprole 10.26 OD @ 1.2 ml l-1, chlorantraniliprole 18.5 SC @0.3 ml l-1, chlorfluazuron 5.4 EC @ 2.0 ml l-1, azadirachtin 1 EC @ 1 ml l-1, spinetoram 11.7 SC + azadirachtin 1 EC @ 0.5 ml l-1 + 1 ml l-1, cyantraniliprole 10.26 OD + azadirachtin 1 EC @ 1.2 ml l-1 + 1 ml l-1, chlorantraniliprole 18.5 SC + azadirachtin 1 EC @ 0.3 ml l-1 + 1 ml l-1, chlorfluazuron 5.4 EC + azadirachtin 1 EC @ 2.0 ml l-1 + 1 ml l-1 and quinalphos 25EC @ 2.0 ml l-1 along with an untreated control. Pooled efficacies of these treatments revealed that chlorantraniliprole 18.5 SC + azadirachtin 1 EC @ 0.3 ml l-1 + 1 ml l-1 was found to be the most effective treatment which exhibited highest efficacy against *Spodoptera litura* (75.26 per cent reduction over control) and

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Achaea janata (82.31 per cent ROC) followed by chlorantraniliprole 18.5 SC @ 0.3 ml l-1 which recorded 68.80 % and 76.15 % ROC respectively. The least per cent ROC was recorded in azadirachtin 1 EC (0.01 %) @ 1 ml l-1.

Keywords: Castor; Spodoptera litura; Achaea janata; Chlorantraniliprole 18.5 SC; Azadirachtin 1 EC.

1. INTRODUCTION

"Castor, *Ricinus communis* (Linneaus) is mostly cultivated in the semi-arid and arid regions in India as a non-edible oilseed crop. It is cultivated in different countries on commercial scale, of which China, India and Brazil are the major castor growing countries accounting for 90 per cent of the world's production. Castor is cultivated in an area of 8.91 lakh ha in world and followed by India with 6.96 lakh ha in 2022-23. The production of castor is about 1.88 million metric tons and mean productivity of castor in 2022 is 1962 kg ha^{-1} (www.statista.com). Gujarat is the major castor producing state accounting for 70 per cent area and 86 per cent production in the country followed by Rajasthan and Andhra Pradesh. Total area of castor in Andhra Pradesh in 2022-23 is 0.56 lakh ha and the total production is 0.37 lakh tonnes with a productivity of 536 kg ha^{-1} (https://des.ap.gov.in). Castor oil is widely used in biodiesel production, pharmaceutical and other industries" [1]. The environmental change and intensive cultivation practices has changed the pests and diseases complex in agricultural crops including castor. Basappa [2] recorded 107 insect pest species, six different mite species infesting castor from seedling to the capsule harvesting. Insect pests, particularly the immature stages *S. litura* and *A. janata* cause great loss in the vegetative stage of the crop and drastically causes yield losses which contributes for 35-40 per cent yield loss.

In Andhra Pradesh castor is mainly grown in Rayalaseema region which receives minimum rainfall and frequent drought spells are most common. Apart from abiotic stress, castor crop is subjected to ravages of insect pests and damage caused by *S. litura* and *A. janata* considered as limiting factor for yield and can cause complete defoliation leading to yield losses up to 80% [3]. Therefore, it is necessary to manage them to increase the productivity of castor. Application of novel molecules have an excellent opportunity in the management of various pests as they are eco-friendly, pest-specific and less persistent. However, information on the Bio-efficacy of the novel molecules and their combination with neem formulation (Azadirachtin) against lepidopteran pests in castor is very limited [4,5]. These combination treatments may act as synergistic effect and also may prevent insecticidal resistance Hence the present study planned to evaluate the novel insecticides against lepidopteran defoliators on castor

2. MATERIALS AND METHODS

The field experiment was conducted at the dry land farm, S.V. Agricultural College, Tirupati during *rabi,* 2021-22. Field (1650 m2) with loamy soil was selected, ploughed thoroughly twice and used blade harrow with tractor to level the field and was laid out in Randomized Block Design with eleven treatments and three replications in a plot size of 8m x 5m (Table 1). A popular hybrid, ICH-66, was sown on 27th October, 2021. The seeds were dibbled with a spacing of 90cm × 45cm. Gap filling was done 10 days after germination and thinning was done 15 days after sowing leaving one healthy seedling per hill and all the recommended agronomic practices were followed except plant protection measures. The treatments were imposed when the pest reached economic threshold level (3-4 larvae plant^{-1}).

Insecticidal treatments were given thrice during the crop period *viz.,* at vegetative stage, at capsule formation stage and at capsule development stage with 30 days interval. Observations on the larval population counts of *S. litura* and *A. janata* were made one day before spraying and at one, three, five and fifteen days after spraying on ten randomly selected and tagged plants in each treatment. The post treatment counts of larvae from various treatments were used to calculate per cent reduction in population over control by using the following formula given by Abbott 1925.

Population reduction over control (%) = Population in untreated check - Population in treatment / Population in untreated check * 100

Table 1. Details of insecticides evaluated against *S. litura and A. janata* of castor during *rabi,* 2021-22

Treatments	Insecticides	Per cent concentration	Dose per litre
T1	Spinetoram 11.7 SC	0.0058 %	0.5 ml l^{-1}
T2	Cyantraniliprole 10.26 OD	0.0123 %	1.2 ml l^{-1}
T3	Chlorantraniliprole 18.5 SC	0.0055 %	0.3 ml l^{-1}
T4	Chlorfluazuron 5.4 EC	0.0108 %	2.0 ml l^{-1}
T5	Azadirachtin 1 EC	0.01 %	1 ml l^{-1}
T6	Spinetoram 11.7 SC + Azadirachtin 1 EC	0.0058 % + 0.01 %	0.5 ml l^{-1} + 1 ml l^{-1}
T7	Cyantraniliprole 10.26 OD + Azadirachtin 1 EC	0.0123 %+ 0.01 %	1.2 ml l^{-1} + 1 ml l^{-1}
T8	Chlorantraniliprole 18.5 SC + Azadirachtin 1 EC	0.0055 % + 0.01 %	0.3 ml l^{-1} + 1 ml l^{-1}
T9	Chlorfluazuron 5.4 EC + Azadirachtin 1 EC	0.0108 % + 0.01 %	2.0 ml l^{-1} + 1 ml l^{-1}
T10	Quinalphos 25EC	0.05 %	2.0 ml l^{-1}
T11	Untreated control	-	Water spray

3. RESULTS AND DISCUSSION

Per cent reduction over untreated control in each spraying of *S. litura* and *A. janata* due to all the three sprayings were calculated and the results are presented in the tables.

3.1 Tobacco Caterpillar *Spodoptera litura*

3.1.1 First spray

The larval population of tobacco caterpillar, *S. litura* in all the treatments was uniform a day before application of treatments as indicated by the non-significant differences among the various treatments (Table 2).

The overall mean efficacy of insecticides after first application revealed that chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent ROC *i.e.,* 76.03 per cent and was found to be the best treatment. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 68.72 and 66.67 per cent ROC respectively and the treatments were statistically at par with each other. The next effective treatments in the descending order of efficacy were cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1}, spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1} with 62.79, 57.76 and 55.25 per cent ROC respectively and were statistically at par with each other. However, the above treatments *viz.,* cyantraniliprole 10.26 OD, spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) and spinetoram 11.7 SC were at par with cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %). Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 40.87 per cent ROC was least effective when compared to above treatments and was significantly different from other treatments (Fig. 1).

3.1.2 Second spray

One day before imposition of treatment, the larval population varied from 2.00 to 3.66 larvae per plant. However, there was significant difference in the larval population among the treatments (Table 2).

The overall efficacy of insecticides after second application revealed that, chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent ROC *i.e.,*75.03 per cent and was found to be the best treatment. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 67.68 and 66.24 per cent ROC respectively and the treatments were statistically at par with each other. The next effective treatments in the descending order of efficacy were cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1}, spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1} with 62.42, 60.03 and 59.24 per cent ROC respectively and were statistically at par with each other. However, the above treatments were at par with cyantraniliprole 10.26 OD. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} (42.20 per cent) was least effective when compared to above treatments and was significantly different from other treatments (Fig. 1).

3.1.3 Third spray

One day before imposition of treatment, the larval population varied from 2.00 to 3.66 larvae per plant. However, there was significant difference in the larval population among the treatments (Table 3).

The overall efficacy of insecticides after third application revealed that, among the insecticidal treatments, the plots treated with chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent ROC *i.e.,* 74.72 per cent and was found to be the best treatment. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 68.06 and 65.82 per cent ROC and the treatments were statistically at par with each other. The next effective treatment was cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1} with 61.49 per cent reduction over control which was at par with cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1}. The next effective treatment was spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1} with 57.76 and 54.63 per cent ROC and were statistically different from others. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 40.90 per cent ROC was least effective when compared to above treatments (Fig. 1). However, all the treatments were significantly superior over control.

When the mean per cent reduction of *S. litura* by various treatments over control was pooled for three sprays, chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest reduction of *S. litura* larval population and remained significantly superior over all the other treatments with 75.26 per cent ROC. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 68.80 and 67.85 per cent reduction over control respectively. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 41.20 per cent reduction over control was least effective when compared to other treatments. However, all the treatments were significantly superior over control (Table 3) (Fig. 1).

3.2 Castor Semilooper, *Achaea janata*

3.2.1 First spray

One day before imposition of treatment, the larval population varied from 1.07 to 2.03 larvae per plant. However, there was significant difference in the larval population among the treatments (Table 4).

The overall efficacy of insecticides after first application revealed that, chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent ROC *i.e.,* 83.63 per cent and was found to be the best treatment. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 77.11 and 73.36 per cent reduction over control respectively and the treatments were statistically at par with each other. The next effective treatments were spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1}, cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1} respectively. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 53.42 per cent ROC was least effective when compared to above treatments (Fig. 2). However, all the treatments were significantly superior over control.

3.2.2 Second spray

One day before imposition of treatment, the larval population varied from 0.75 to 2.40 larvae per plant. However, there was significant difference in the larval population among the treatments (Table 4).

The overall efficacy of insecticides after second application revealed that, chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent ROC *i.e.,* 82.96 per cent and the treatment was found to be the best treatment. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 77.73 and 75.46 per cent ROC respectively and the treatments were statistically at par with each other. The next effective treatments were spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1}, cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1}. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 50.69 per cent ROC was least effective when compared to above treatments (Fig. 2). However, all the treatments were significantly superior over control.

3.2.3 Third spray

One day before imposition of treatment, the larval population varied from 1.02 to 2.47 larvae per plant. However, there was significant difference in the larval population among the treatments (Table 5).

The overall efficacy of insecticides after third application revealed that, plots treated with chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent ROC *i.e.,* 82.45 per cent and was found to be the best treatment. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 78.63 and 76.83 per cent reduction over control respectively and the treatments were statistically at par with each other. The next effective treatments were spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1}, cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1} respectively. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 51.85 per cent ROC was least effective when compared to above treatments (Fig. 2). However, all the treatments were significantly superior over control.

When the mean per cent reduction of *A. janata* by various treatments over control was pooled for three sprays, chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest reduction of larval population and remained significantly superior over all the other treatments with 82.31 per cent ROC. The next effective treatments in the descending order of efficacy were chlorantraniliprole 18.5 SC (0.0055 %) @ 0.3 ml l^{-1} and cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1} with 76.15 and 74.78 per cent ROC respectively. The next best treatments were spinetoram 11.7 SC (0.0058 %) + azadirachtin 1 EC (0.01 %) @ 0.5 ml l^{-1} + 1 ml l^{-1} with 72.96 and was on par with cyantraniliprole 10.26 OD (0.0123 %) + azadirachtin 1 EC (0.01 %) @ 1.2 ml l^{-1} + 1 ml l^{-1}. The next effective treatments were cyantraniliprole 10.26 OD (0.0123 %) @ 1.2 ml l^{-1} and spinetoram 11.7 SC (0.0058 %) @ 0.5 ml l^{-1}. Azadirachtin 1 EC (0.01 %) @ 1 ml l^{-1} with 51.67 per cent ROC was least effective when compared to above treatments (Table 5) (Fig. 2).

The results are in accordance with Jayanth and Kumar [6] who reported that chlorantraliprole 18.5 % SC + neem oil 1 % was found to be the most effective treatment against gram pod borer *H. armigera* in chickpea by recording 1.25 mean larval population. Gadhiya et al. [7] who found that chlorantraniliprole was superior in reducing the incidence of *S. litura* in groundnut with the lowest leaf damage of 5.67 per cent. The results were also in confirmity with the findings of Sreekanth et al. [8]. Rashmi et al. [89 reported that chlorantraniliprole 18.5 SC was found to be most effective treatment against all the pod borers of field bean with the lowest pod damage of 12.57 per cent. The results were also in agreement with that of Chaudhari et al. [10] who reported that at fourteen days after spray chlorantraniliprole 18.5 SC (2.17 mean larval population) was found to be effective against *S. litura*. Waykule et al. [11] reported that chlorantraniliprole 18.5 SC was found to be most effective against *S. litura* (1.13 larva plant^{-1}) on groundnut.

The studies are also in accordance with Manjunatha et al. [12] who reported chlorantraniliprole was most effective (79.53 % mortality) in the control of castor semilooper. (Narayanamma et al. 2013) who reported that chlorantraniliprole was found to be the most effective against *A. janata* (0.40 larvae plant^{-1}). Duraimurugan and Lakshminarayana [13] reported that chlorantraniliprole 18.5 SC was found to be the best treatment against A. janata (100 per cent ROC). Ranganath et al. [14] reported that chlorantraniliprole 18.5 SC was found to be best treatment against A. janata (87.50 per cent ROC). The results were in confirmity with the findings of Wale et al. [15] who reported that cyantraniliprole 10 SE was

Table 2. Efficacy of different insecticides against tobacco caterpillar after first and second sprays during rabi, 2021-22

S.No.	Treatments	Dosage	per cent reduction of tobacco caterpillar larval population over control											
			First spray						Second spray					
			PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction	PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction
T_1	Spinetoram 11.7 SC	0.5 ml l^{-1}	1.00	45.10^{bc} (42.11)	69.90^{c} (56.69)	60.00^{cd} (50.61)	47.15^{cd} (43.31)	55.25^{cd} (48.01)	1.45	45.33^{bc} (42.18)	70.27^{c} (56.91)	57.24^{cd} (49.21)	47.19^{cd} (43.41)	59.24^{cd} (47.37)
T_2	Cyantraniliprole 10.26 OD	1.2 ml l^{-1}	0.90	53.92^{ab} (47.19)	78.64^{bc} (62.51)	67.27^{bc} (55.10)	52.85^{c} (46.53)	62.79^{c} (52.58)	1.33	52.00^{abc} (46.14)	78.38^{bc} (62.26)	65.13^{bc} (53.77)	51.69^{c} (45.93)	62.42^{c} (51.62)
T_3	Chlorantraniliprole 18.5 SC	0.3 ml l^{-1}	0.93	57.84^{a} (49.46)	84.47^{b} (66.93)	71.82^{b} (57.93)	61.79^{b} (51.79)	68.72^{b} (56.11)	1.20	58.67^{a} (49.99)	83.11^{b} (65.79)	69.74^{b} (56.60)	60.67^{b} (51.22)	67.68^{b} (56.13)
T_4	Chlorfluazuron 5.4 EC	2.0 ml l^{-1}	1.17	38.24^{cd} (37.83)	61.17^{d} (51.45)	53.64^{d} (47.08)	39.84^{d} (39.02)	47.08^{e} (43.88)	1.55	38.67^{cd} (38.44)	60.81^{d} (51.16)	51.32^{d} (45.74)	40.45^{d} (39.47)	49.17^{e} (45.00)
T_5	Azadirachtin 1 EC	1 ml l^{-1}	1.30	28.43^{d} (32.18)	58.25^{d} (49.75)	44.55^{e} (41.86)	33.33^{e} (35.13)	40.87^{g} (39.82)	1.67	35.33^{d} (36.47)	56.08^{d} (48.49)	40.79^{e} (39.59)	33.71^{e} (35.45)	42.20^{f} (43.99)
T_6	Spinetoram 11.7 SC + Azadirachtin 1 EC	0.5 ml l^{-1} + 1 ml l^{-1}	1.00	47.06^{b} (43.15)	72.82^{c} (58.57)	62.73^{c} (52.37)	49.59^{c} (44.71)	57.76^{c} (49.55)	1.40	47.33^{bc} (43.47)	72.30^{c} (58.23)	59.87^{c} (50.67)	50.00^{c} (44.93)	60.03^{c} (49.58)
T_7	Cyantraniliprole 10.26 OD + Azadirachtin 1 EC	1.2 ml l^{-1} + 1 ml l^{-1}	0.83	56.86^{a} (48.83)	(64.56) 90.29^{a}	70.91^{b} (57.35)	58.54^{bc} (49.89)	66.67^{bc} (54.87)	1.20	55.33^{ab} (48.06)	81.08^{b} (64.21)	66.45^{b} (54.76)	57.30^{bc} (49.17)	66.24^{bc} (53.80)
T_8	Chlorantraniliprole 18.5 SC + Azadirachtin 1 EC	0.3 ml l^{-1} + 1 ml l^{-1}	0.87	59.80^{a} (50.60)	(71.87) 67.00^{cd}	78.18^{a} (62.15)	67.48^{a} (55.48)	76.03^{a} (59.36)	1.13	60.67^{a} (51.15)	88.51^{a} (70.72)	75.00^{a} (60.01)	66.29^{a} (54.70)	75.03^{a} (58.85)
T_9	Chlorfluazuron 5.4 EC + Azadirachtin 1 EC	2.0 ml l^{-1} + 1 ml l^{-1}	1.13	39.22^{c} (38.77)	(54.93) 60.19^{d}	55.45^{d} (48.13)	40.65^{d} (39.55)	50.23^{d} (45.22)	1.62	40.00^{c} (40.78)	67.57^{cd} (55.27)	51.97^{d} (46.08)	42.13^{d} (40.45)	52.07^{e} (46.82)
T_{10}	Quinalphos 25EC (Check)	2.0 ml l^{-1}	1.30	29.41^{d} (32.84)	60.19^{d} (50.88)	50.00^{d} (45.00)	38.21^{d} (38.22)	44.29^{f} (41.78)	1.67	37.33^{d} (37.66)	58.78^{d} (50.02)	48.68^{de} (44.20)	38.20^{d} (38.12)	47.77^{e} (46.09)
T_{11}	Untreated control		1.70	-	-	-	-	-	2.50	-	-	-	-	-
SEm±				1.60	1.41	1.62	1.60	0.90		1.39	1.45	1.61	1.65	0.76
CD (5 %)			NS	4.73	4.15	4.79	4.71	2.66	NS	4.09	4.27	4.75	4.88	2.25
CV (%)				7.24	4.56	5.98	6.85	3.50		6.11	4.73	6.13	7.12	2.98

Figures in parentheses are angular transformed values
PTC: Pre-treatment count
DAS: Days After Spraying

Table 3. Efficacy of different insecticides against tobacco caterpillar after third spray and pooled data during *rabi,* 2021-22

S.No.	Treatments	Dosage	per cent reduction of tobacco caterpillar larval population over control											
			Third spray						Pooled data					
			PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction	PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction
T$_1$	Spinetoram 11.7 SC	0.5 ml l^{-1}	1.55	44.94^{bc} (42.02)	70.63^{c} (57.18)	54.71^{cd} (47.72)	48.90^{cd} (44.33)	54.63^{e} (47.74)	1.33	50.78^{cd} (45.48)	73.63^{cd} (59.11)	56.94^{e} (48.98)	48.45^{cd} (44.12)	55.85^{e} (49.29)
T$_2$	Cyantraniliprole 10.26 OD	1.2 ml l^{-1}	1.33	54.43^{abc} (47.54)	78.75^{bc} (62.54)	60.00^{c} (50.76)	53.85^{c} (47.18)	61.49^{cd} (52.28)	1.19	53.41^{c} (46.94)	78.59^{c} (62.44)	64.58^{cd} (53.53)	52.80^{c} (46.58)	61.98^{c} (52.15)
T$_3$	Chlorantraniliprole 18.5 SC	0.3 ml l^{-1}	1.23	59.49^{a} (50.43)	83.75^{b} (66.27)	68.24^{b} (55.79)	61.54^{b} (51.68)	68.06^{b} (56.63)	1.12	57.32^{b} (49.19)	83.80^{b} (66.03)	69.68^{b} (56.60)	61.28^{b} (51.54)	68.80^{b} (56.04)
T$_4$	Chlorfluazuron 5.4 EC	2.0 ml l^{-1}	1.72	38.61^{cd} (38.41)	63.13^{d} (52.57)	47.06^{d} (43.31)	37.36^{e} (37.67)	47.94^{e} (45.44)	1.48	38.10^{d} (38.08)	65.69^{d} (54.14)	50.23^{fg} (45.13)	39.13^{d} (38.72)	49.25^{g} (44.57)
T$_5$	Azadirachtin 1 EC	1 ml l^{-1}	1.77	34.18^{d} (35.77)	58.13^{d} (49.67)	39.41^{e} (38.88)	32.97^{f} (34.96)	40.90^{g} (42.25)	1.58	33.17^{e} (35.15)	59.12^{e} (50.25)	40.56^{h} (39.56)	33.33^{e} (35.26)	41.20^{i} (39.93)
T$_6$	Spinetoram 11.7 SC + Azadirachtin 1 EC	0.5 ml l^{-1} + 1 ml l^{-1}	1.48	47.47^{bc} (43.54)	72.50^{c} (58.40)	58.82^{c} (50.08)	52.75^{c} (46.56)	57.76^{d} (50.00)	1.29	52.44^{c} (46.42)	76.20^{c} (60.82)	60.42^{d} (51.01)	50.93^{c} (45.53)	58.19^{d} (49.71)
T$_7$	Cyantraniliprole 10.26 OD + Azadirachtin 1 EC	1.2 ml l^{-1} + 1 ml l^{-1}	1.27	56.96^{ab} (49.00)	81.88^{b} (64.80)	65.88^{bc} (54.26)	59.34^{bc} (50.39)	65.82^{bc} (54.61)	1.10	56.54^{bc} (48.75)	81.51^{bc} (64.55)	65.93^{c} (54.29)	59.63^{bc} (50.57)	67.85^{bc} (55.45)
T$_8$	Chlorantraniliprole 18.5 SC + Azadirachtin 1 EC	0.3 ml l^{-1} + 1 ml l^{-1}	1.25	61.39^{a} (51.58)	90.00^{a} (71.77)	76.47^{a} (60.98)	67.03^{a} (55.39)	74.72^{a} (59.40)	1.08	60.73^{a} (51.19)	89.54^{a} (71.13)	76.39^{a} (61.01)	66.87^{a} (54.93)	75.26^{a} (63.79)
T$_9$	Chlorfluazuron 5.4 EC + Azadirachtin 1 EC	2.0 ml l^{-1} + 1 ml l^{-1}	1.70	39.87^{c} (39.15)	68.13^{cd} (55.62)	48.82^{d} (44.32)	42.86^{d} (40.84)	49.70^{e} (46.63)	1.48	40.73^{d} (39.60)	67.64^{d} (55.33)	51.62^{f} (45.92)	42.03^{d} (40.40)	50.33^{f} (45.32)
T$_{10}$	Quinalphos 25EC (Check)	2.0 ml l^{-1}	1.85	33.54^{d} (35.39)	61.88^{d} (51.86)	46.47^{d} (42.96)	37.36^{e} (37.68)	44.63^{f} (42.42)	1.61	37.07^{d} (37.50)	63.50^{e} (52.84)	48.15^{g} (43.94)	37.89^{d} (37.98)	46.31^{h} (42.88)
T$_{11}$	Untreated control		2.60	-	-	-	-	-	2.27	-	-	-	-	-
SEm±				1.44	1.47	1.69	1.80	0.71		0.94	1.14	0.98	1.11	0.53
CD (5 %)			NS	4.25	4.35	5.00	5.31	2.08	NS	2.77	3.35	2.90	3.27	1.59
CV (%)				6.36	4.75	6.60	7.68	2.74		4.09	3.63	3.75	4.74	2.81

Figures in parentheses are angular transformed values
PTC: Pre-treatment count
DAS: Days After Spraying

Table 4. Efficacy of different insecticides against castor semilooper after first and second sprays during rabi, 2021-22

S.No.	Treatments	Dosage	per cent reduction of castor semilooper larval population over control											
			First spray						Second spray					
			PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction	PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction
T_1	Spinetoram 11.7 SC	0.5 ml l^{-1}	1.30	56.82^{cd} (47.74)	76.32^{d} (60.90)	76.32^{d} (60.90)	71.88^{d} (57.99)	67.51^{de} (54.96)	1.37	56.17^{bc} (48.56)	75.00^{c} (60.01)	64.94^{cd} (53.70)	62.50^{cd} (52.24)	64.85^{e} (53.52)
T_2	Cyantraniliprole 10.26 OD	1.2 ml l^{-1}	1.25	58.33^{bcd} (48.63)	78.29^{cd} (62.22)	78.29^{cd} (62.22)	72.92^{c} (58.81)	69.05^{d} (55.90)	1.27	57.41^{bc} (49.26)	77.08^{c} (61.40)	69.56^{c} (56.52)	65.00^{c} (53.75)	67.56^{d} (55.10)
T_3	Chlorantraniliprole 18.5 SC	0.3 ml l^{-1}	1.07	68.18^{ab} (54.69)	86.18^{b} (68.22)	86.18^{b} (68.22)	80.00^{b} (63.48)	77.11^{b} (61.24)	1.18	68.52^{a} (55.96)	86.46^{b} (68.60)	79.70^{b} (63.57)	75.17^{b} (60.16)	77.73^{b} (61.66)
T_4	Chlorfluazuron 5.4 EC	2.0 ml l^{-1}	1.43	49.24^{e} (43.20)	68.42^{e} (55.81)	68.42^{e} (55.81)	65.63^{d} (54.16)	60.22^{f} (50.58)	1.58	48.77^{cd} (44.29)	67.71^{d} (55.37)	59.87^{de} (50.71)	54.58^{de} (47.63)	60.14^{f} (49.45)
T_5	Azadirachtin 1 EC	1 ml l^{-1}	1.63	41.67^{f} (38.55)	64.47^{e} (53.41)	64.47^{e} (53.41)	59.58^{e} (50.53)	53.42^{h} (46.71)	1.72	40.74^{d} (39.65)	63.54^{d} (52.87)	49.72^{f} (44.85)	47.00^{e} (43.85)	50.69^{h} (45.29)
T_6	Spinetoram 11.7 SC + Azadirachtin 1 EC	0.5 ml l^{-1} + 1 ml l^{-1}	1.17	64.39^{abc} (52.32)	83.55^{bc} (66.11)	83.55^{bc} (66.11)	76.56^{bc} (61.10)	73.11^{c} (58.66)	1.22	64.20^{abc} (53.27)	82.29^{bc} (65.13)	74.17^{bc} (59.48)	67.92^{c} (55.74)	72.25^{c} (58.19)
T_7	Cyantraniliprole 10.26 OD + Azadirachtin 1 EC	1.2 ml l^{-1} + 1 ml l^{-1}	1.05	5.91^{abc} (53.26)	84.87^{b} (67.33)	84.87^{b} (67.33)	78.13^{b} (62.14)	73.36^{bc} (60.05)	1.08	66.05^{ab} (54.43)	84.38^{b} (66.73)	77.86^{b} (61.94)	72.50^{bc} (58.46)	75.46^{b} (60.16)
T_8	Chlorantraniliprole 18.5 SC + Azadirachtin 1 EC	0.3 ml l^{-1} + 1 ml l^{-1}	1.07	69.70^{a} (55.67)	90.79^{a} (72.40)	90.79^{a} (72.40)	85.42^{a} (67.59)	83.63^{a} (64.35)	1.12	72.22^{a} (58.29)	92.71^{a} (74.41)	85.15^{a} (67.44)	80.42^{a} (63.77)	82.96^{a} (65.43)
T_9	Chlorfluazuron 5.4 EC + Azadirachtin 1 EC	2.0 ml l^{-1} + 1 ml l^{-1}	1.33	54.55^{de} (46.31)	73.68^{de} (59.15)	73.68^{de} (59.15)	68.23^{d} (55.71)	63.73^{e} (52.84)	1.47	51.23^{c} (45.71)	72.40^{cd} (58.32)	62.18^{d} (52.06)	56.25^{d} (48.59)	61.52^{f} (51.07)
T_{10}	Quinalphos 25EC (Check)	2.0 ml l^{-1}	1.60	45.45^{f} (40.84)	66.45^{e} (54.65)	66.45^{e} (54.65)	63.54^{d} (52.88)	57.56^{g} (48.97)	1.70	43.21^{d} (41.09)	65.63^{d} (54.12)	54.80^{e} (47.76)	52.08^{de} (46.19)	56.34^{g} (47.25)
T_{11}	Untreated control		2.03	-	-	-	-	-	2.40	-	-	-	-	-
SEm±				1.42	1.15	1.15	1.62	0.81		1.49	1.02	1.61	1.74	0.80
CD (5 %)			NS	4.19	3.40	3.40	4.78	2.39	NS	4.40	3.00	4.74	5.14	2.36
CV (%)				5.62	3.54	3.54	5.28	2.78		5.80	3.15	5.49	6.26	2.79

Figures in parentheses are angular transformed values
PTC: Pre-Treatment Count
DAS: Days After Spraying

Table 5. Efficacy of different insecticides against castor semilooper after third spray and overall cumulative efficacy during *rabi,* 2021-22

S.No.	Treatments	Dosage	per cent reduction of castor semilooper larval population over control											
			Third spray						Pooled data					
			PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction	PTC	1 DAS	5 DAS	10 DAS	15 DAS	Mean per cent reduction
T_1	Spinetoram 11.7 SC	0.5 ml l^{-1}	1.33	58.33^{bc} (49.80)	76.80^{c} (61.20)	66.67^{d} (54.83)	60.96^{cd} (51.38)	60.53^{de} (54.15)	1.34	56.58^{cd} (48.79)	76.02^{de} (60.68)	67.68^{d} (55.37)	62.92^{cd} (52.49)	66.49^{d} (54.21)
T_2	Cyantraniliprole 10.26 OD	1.2 ml l^{-1}	1.35	61.31^{bc} (51.60)	78.35^{c} (62.33)	69.52^{cd} (56.49)	64.47^{c} (53.42)	61.42^{d} (55.82)	1.28	58.55^{c} (49.94)	77.88^{d} (61.95)	70.59^{d} (57.18)	65.45^{c} (54.00)	68.34^{d} (55.62)
T_3	Chlorantraniliprole 18.5 SC	0.3 ml l^{-1}	1.17	70.24^{a} (56.95)	88.14^{b} (69.90)	80.95^{b} (64.17)	74.56^{b} (59.92)	78.63^{b} (62.40)	1.16	68.64^{b} (55.94)	86.99^{b} (68.87)	80.22^{b} (63.62)	74.78^{b} (59.90)	76.15^{b} (61.79)
T_4	Chlorfluazuron 5.4 EC	2.0 ml l^{-1}	1.53	49.40^{cd} (44.66)	70.62^{d} (57.18)	61.43^{e} (51.63)	52.19^{d} (46.26)	56.75^{e} (49.84)	1.57	48.46^{d} (44.13)	68.96^{g} (56.16)	62.18^{ef} (52.06)	54.92^{d} (47.82)	59.75^{f} (49.97)
T_5	Azadirachtin 1 EC	1 ml l^{-1}	1.70	42.14^{d} (40.46)	67.53^{d} (55.26)	53.81^{f} (47.20)	41.23^{e} (39.91)	51.85^{g} (45.67)	1.69	40.75^{e} (39.67)	65.24^{i} (53.87)	54.17^{g} (47.40)	46.24^{e} (42.83)	51.67^{h} (45.91)
T_6	Spinetoram 11.7 SC + Azadirachtin 1 EC	0.5 ml l^{-1} + 1 ml l^{-1}	1.08	65.48^{ab} (54.06)	84.02^{bc} (66.40)	74.48^{bcd} (59.68)	67.54^{c} (55.31)	63.90^{c} (58.60)	1.14	64.25^{c} (53.31)	83.27^{c} (65.86)	75.02^{cd} (60.02)	68.26^{c} (55.73)	72.96^{c} (58.50)
T_7	Cyantraniliprole 10.26 OD + Azadirachtin 1 EC	1.2 ml l^{-1} + 1 ml l^{-1}	1.07	67.26^{a} (55.12)	86.08^{b} (68.40)	76.95^{bc} (61.34)	72.37^{bc} (58.29)	76.83^{b} (60.48)	1.01	66.01^{c} (54.36)	85.13^{bc} (67.41)	77.63^{c} (61.79)	72.61^{bc} (58.48)	74.78^{bc} (60.26)
T_8	Chlorantraniliprole 18.5 SC + Azadirachtin 1 EC	0.3 ml l^{-1} + 1 ml l^{-1}	1.02	72.62^{a} (58.48)	92.78^{a} (74.39)	86.19^{a} (68.41)	81.58^{a} (64.78)	82.45^{a} (65.86)	1.03	71.27^{a} (57.59)	92.19^{a} (73.78)	85.59^{a} (67.71)	80.90^{a} (64.16)	82.31^{a} (65.27)
T_9	Chlorfluazuron 5.4 EC + Azadirachtin 1 EC	2.0 ml l^{-1} + 1 ml l^{-1}	1.43	52.98^{c} (46.71)	74.74^{cd} (59.79)	64.76^{de} (53.59)	55.70^{d} (48.28)	58.00^{e} (51.96)	1.39	52.19^{d} (46.24)	73.61^{f} (59.08)	64.93^{de} (53.70)	57.30^{d} (49.19)	63.00^{e} (51.94)
T_{10}	Quinalphos 25EC (Check)	2.0 ml l^{-1}	1.65	44.64^{d} (41.92)	69.07^{d} (56.08)	59.52^{e} (50.51)	49.12^{d} (44.50)	54.22^{f} (48.16)	1.67	43.64^{d} (41.34)	67.10^{h} (54.99)	59.11^{f} (50.26)	52.11^{d} (46.20)	55.78^{g} (48.14)
T_{11}	Untreated control		2.47	-	-	-	-	-	2.30	-	-	-	-	-
SEm±				1.50	1.17	1.68	1.79	0.78		0.90	0.66	0.94	1.02	0.53
CD (5 %)			NS	4.41	3.44	4.96	5.28	2.31	NS	2.65	1.94	2.78	3.02	1.57
CV (%)				5.70	3.52	5.64	6.53	2.70		3.48	2.01	3.15	3.68	2.50

Figures in parentheses are angular transformed values
PTC: Pre-treatment count
DAS: Days After Spraying

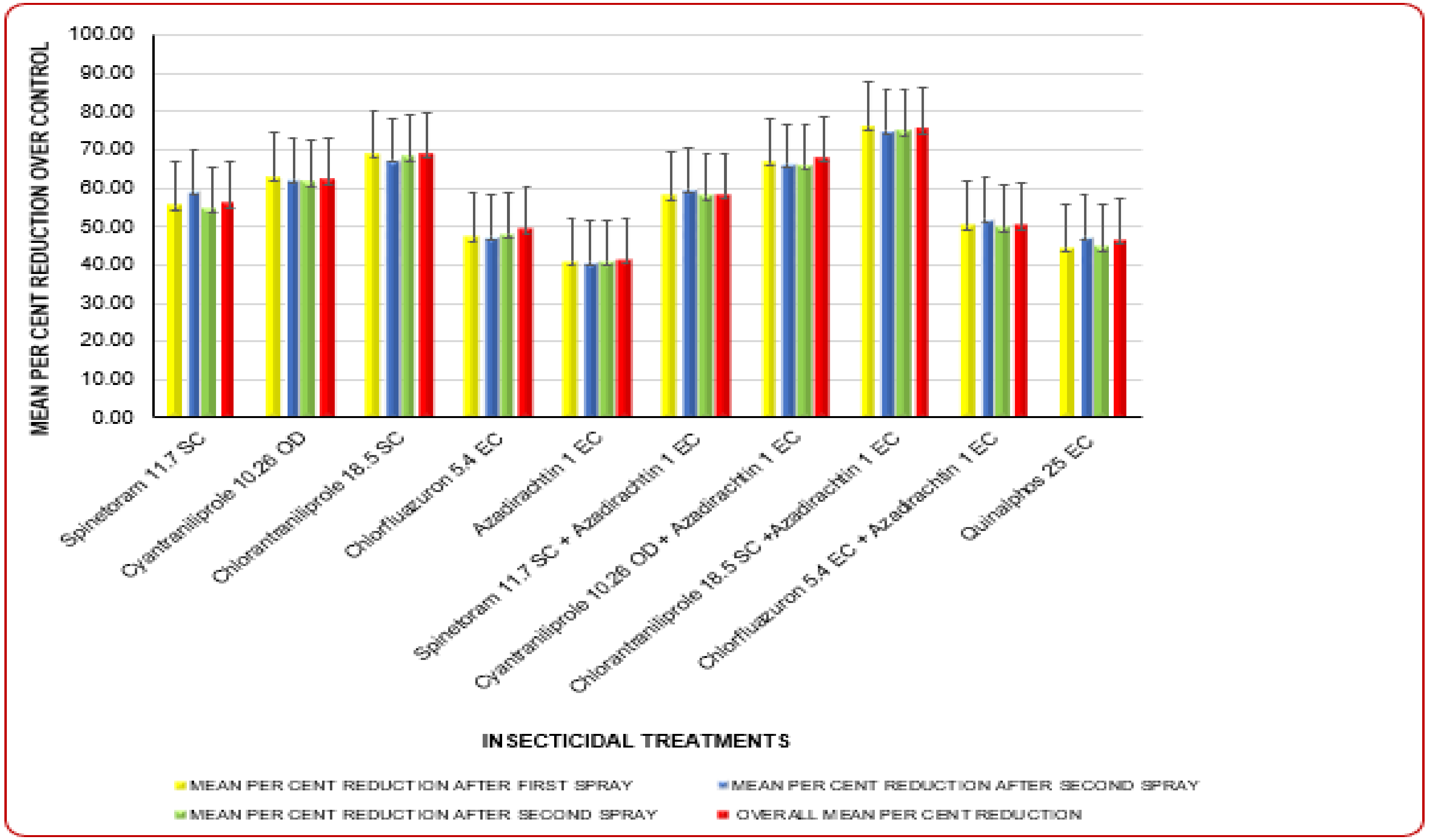

Fig. 1. Mean effect of treatments after three sprays against tobacco caterpillar during rabi, 2021-22

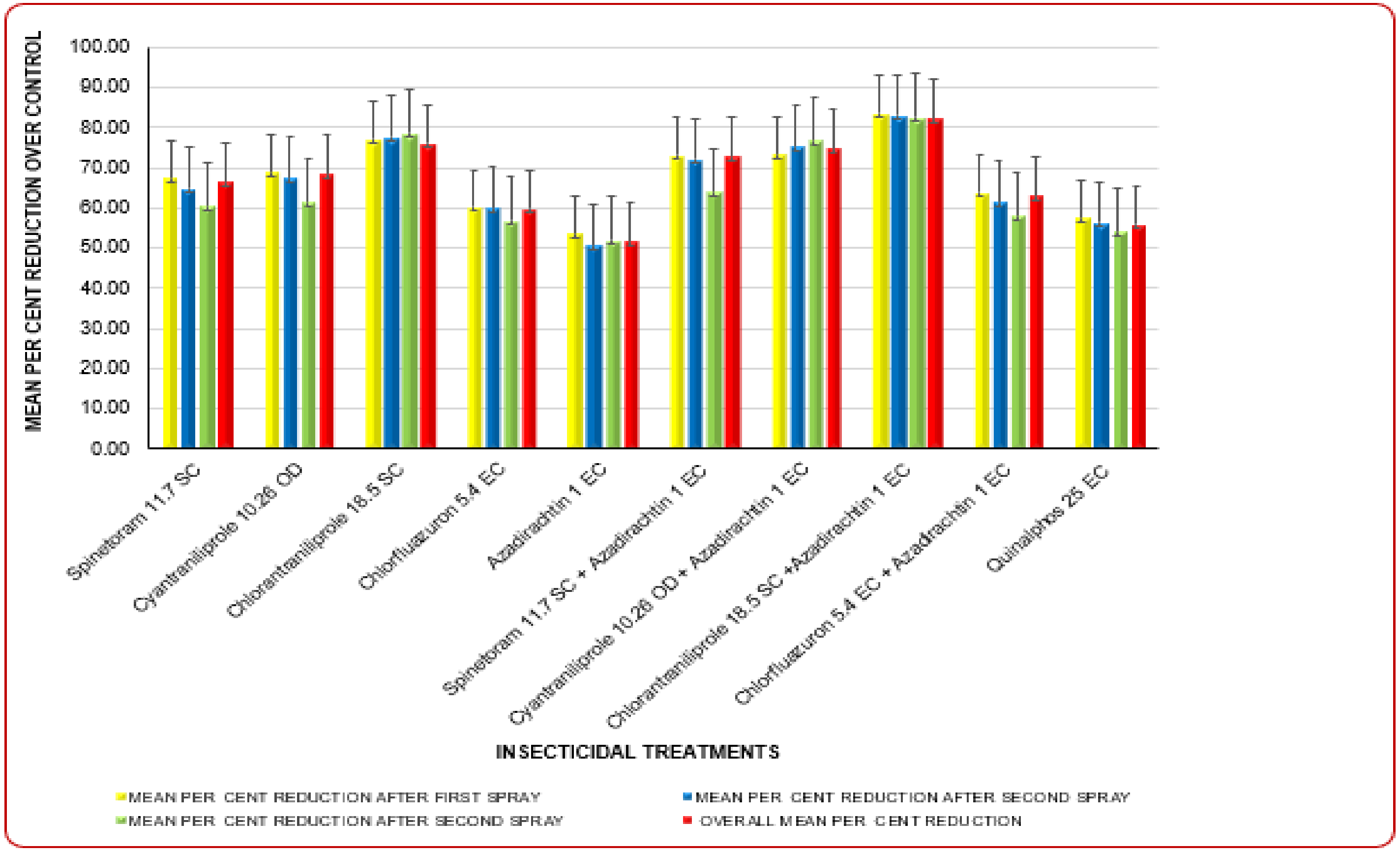

Fig. 2. Mean effect of treatments after three sprays against castor semilooper during rabi, 2021-22

found to be effective against *H. armigera* with 0.45 larvae plant^{-1} in pigeonpea. (Harshita et al. [16] reported that application of cyantraniliprole 10 OD recorded the least larval population of 0.92 larvae plant^{-1} and lowest pod damage of 6.90 per cent against pod borer complex in pigeonpea with higher green pod yield. Prashant [17-19] reported that flubendiamide 480 SC followed by cyantraniliprole 10 OD was found to be effective in reducing the larval population of *S. litura* in soyabean with 84.03 and 75.99 per cent reduction over control respectively [20,21,5].

4. CONCLUSION

Among the novel insecticides evaluated against *S. litura* and *A. janata* of castor, it reveals that all the tested treatments were effective in reducing the infestation of *S. litura* and *A. janata* of castor over untreated control. Chlorantraniliprole 18.5 SC (0.0055 %) + azadirachtin 1 EC (0.01 %) @ 0.3 ml l^{-1} + 1 ml l^{-1} recorded highest per cent reduction over control followed by chlorantraniliprole 18.5 % SC. The highest per cent reduction of *S. litura* and *A. janata* of castor in the treatment chlorantraniliprole 18.5 SC + azadirachtin 1 EC @ 0.3 ml l^{-1} + 1 ml l^{-1} might be due to the combined mode of action of these two compounds compared to other insecticides. Rao and Dhingra (2000) reported antifeedant effect of neem and synthetic pyrethroids against *S. litura*. The novel mode of actions might have contributed for the superior efficacy of chlorantraniliprole with azadirachtin. Therefore, the combination of insecticides with neem formulations such as azadirachtin (0.01 %) fits very well into Integrated Pest Management programme.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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