fficacy of diamide insecticides delivered through different methods against shoot and fruit borer *L. orbonalis.*

Abstract:

Many vegetables insect pests are managed by using conventional insecticides. Unfortunately, these insecticides are harmful to natural enemies, bees, predators, parasitoids and no longer have some of the insect pests have developed resistance to these insecticides. Diamides insecticides are the new generation insecticides that provide systemic way controlling many arthropod pest, but exhibit low toxicity to beneficial insects some other arthropod pests and may be promising alternative to other conventional insecticides.Field experiment was carried out to evaluate the efficacy of diamides delivered through different during *Kharif*, 2021-22 with 14 treatments and 2 replications. Diamides may be delivered to brinjal crop via seedling dipping, soil drenching and foliar spraying therefore it is important to determine the most effective pest control strategy while using the least amount of active ingredients. In a case study, chlorantraniliprole flubendiamide and cyantraniliprole were used to control brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Pyraustidae) in brinjal. These insecticides administered as foliar spray, soil drenching and seedling dipping were compared, the treatment with foliar application of diamides gave good results as compared to soil drenching and seedling dipping. The results indicated that, diamides were superior to other insecticides used in the present investigation but they failed to give good control when applied through seedling dipping method. Highest C:B ratio (1: 6.07) and yield (47.80t/ha) was recorded in foliar spray of chlorantraniliprole 18.5 SC treated plot.

Key Words:, chlorantraniliprole, flubendiamide, foliar spray,*Leucinodes orbonalis*

1. Introduction

Brinjal (*Solanum melongena* L.) is the most significant vegetable crop and sensitive perennial plant farmed globally for its edible fruit. It belongs to the Solanaceae family. Brinjal is used as an Ayurvedic medication to treat diabetes, as well as an appetizer, aphrodisiac, cardiac tonic, laxative, and inflammation reliever (Nandi *et.*, *al* 2017).

Brinjal is cultivated in an area of 1.8 million hectare globally, with a production of 55.1 million tonnes and a productivity of 29.87 tonnes per ha, whereas in India, brinjal is grown all year in an area of about 749 thousand ha, with a production of 12874 thousand million tonnes and a productivity of 17.44 tonnes per ha (Anon, 2019a). India's primary brinjal-growing states include Maharashtra, Madhya Pradesh, Bihar, Punjab, and Tamil Nadu. Brinjal is farmed on 11.29 hectares in Karnataka, with a production of 300.52 million tons and a productivity of 25 tonnes per hectare. In Vijayapur, brinjal is cultivated in an area of 695 hectares, with a production of 17,375 million tonnes. (Prashanth *et al.*, 2023).

Due to unique chemical structure and novel mode of action with translaminar action these diamides shows excellent control of pest populations resistant to other conventional insecticides like organophosphates and carbamates. As all the conventional insecticides act on nervous system these diamides act mainly on muscle system. The diamides products are remarkably potent with insect pests, they work on insects' resistance to other chemistries, they have great rotational partners with other products. Diamides with unique mode of action and safety to predators, parasitoids, environment with low mammalian toxicity. Many vegetable insect pests are managed using neonicotinoid and pyrethroid insecticides. Unfortunately, these insecticides are toxic to many bees and natural enemies and no longer control and some pests that have developed resistance. Anthranilic diamide insecticides provide systemic control of many herbivorous arthropod pests, but exhibit low toxicity to beneficial arthropods and mammals and may be a promising alternative to neonicotinoids and pyrethroids.

2. Materials and Methods

Field trials was conducted on brinjal hybrid (Super Mahyco 10) planted with a spacing of 120X60cm during2021 at the College of Agriculture, Vijayapura, Karnataka having plot size 6.0 m X 3 m per treatment per replication. Spray application was done using high volume knapsack sprayer fitted with hollow cone nozzle covering the entire plant. Soil drenching was done by removing the nozzle and directing the discharge line towards the base of the plant. Spray solution was released around the base of the plant uniformly for all the plants. Seedling dipping was done in the insecticide solution of known concentration (0.3ml) for 3 minutes before transplanting. Two applications of diamides through soil drenching and foliar spray were applied at 20 days interval during the vegetative stage of the crop to assess the shoot damage. Similarly, two applications of diamides through soil drenching and foliar spray were given during the fruiting stage of the crop at 20 days interval to assess the fruit damage. Applications were done when the pest reached ETL. Water was used to dilute the spray solution at a rate of 500-600 L/ha.

Data recording and analysis:

Pre-treatment observations on shoot damage were recorded one day prior to the delivery of insecticides and post treatment observations were taken at 1, 3, 5 and 7 days after delivery of insecticides. Similar procedure was adopted to assess the fruit damage also.

Later percent shoot damage and fruit damage was calculated using the formulae

$$\text{Percentage of Shoot damage (\%)} = \frac{\text{Number of infested shoots}}{\text{Number of total shoots}} \times 100$$

$$\text{Percentage of Fruit damage (\%)} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

The data from management trails were subjected to one way ANOVA by using Web Agri Stat Package (WASP-2.0) developed by Indian Council of Agriculture Research Complex, Goa.

3. **Results and discussion:**

Data on mean per cent shoot damage after two applications revealed the superiority of foliar applications of diamides and soil drenching of chlorantraniliprole 18.5 SC which were found on par with each other and recorded significantly lowest shoot damage (11.92, 13.73, 13.03 and 14.36 %) for foliar sprays chlorantraniliprole 18.5 SC, cyantraniliprole 10OD, flubendiamide 480SC and soil drenching of chlorantraniliprole 18.5 SC respectively.) and they were on par with higher dose of chlorantraniliprole 18.5 SC(11.50%). This was followed by soil drenching of cyantraniliprole 10OD (16.94%), soil drenching of flubendiamide 480SC (14.92%) which were at par and on par with emamectin benzoate 5SG (17.23%). Spinosad 45SC (18.25%) and azadirachtin 300ppm (19.96%) were found at par and significantly superior to seedling dipping of three diamides which recorded significantly highest per cent shoot damage compared to all other treatments (22.56, 24.40 and 23.77% for chlorantraniliprole 18.5 SC, cyantraniliprole 10OD and flubendiamide 480SC. UTC recorded significantly highest mean per cent shoot damage (34.85%).

The data on mean per cent reduction in shoot damage over control indicated that, maximum reduction was recorded under higher dose of chlorantraniliprole 18.5 SC(63.13) followed by foliar spray of chlorantraniliprole 18.5 SC@0.3ml (62.04), foliar spray of flubendiamide 480SC (58.95), foliar spray of cyantraniliprole 10OD (56.96) soil drenching of chlorantraniliprole 18.5 SC (56.63), soil drenching of flubendiamide 480SC (53.35), soil drenching of cyantraniliprole 10OD (47.01), emamectin benzoate 5SG (45.83), spinosad 45SC (42.42), azadirachtin 300ppm (36.86), seedling dipping of chlorantraniliprole 18.5 SC (30.42), seedling dipping of flubendiamide 480SC (26.35), seedling dipping of cyantraniliprole 10OD (24.67) (Fig 1).

Seedling dipping was done before transplanting, whereas, soil drenching and foliar spray were given twice during cropping period. Among the three methods of application of diamides, foliar spray was found to be best method followed by soil drenching. Seedling dipping method performed poor.

Mean of two applications with respect to per cent fruit damage revealed significant difference among the treatments and foliar application of diamides proved to be significantly superior by recording lowest per cent fruit damage (10.60, 11.49 and 11.54%for chlorantraniliprole 18.5SC, flubendiamide 480SC and cyantraniliprole 10OD respectively). They were found on par with higher dose of chlorantraniliprole 18.5 SC (10.34%). Next best method of application was found to be soil drenching and three diamides applied through this method were found to be at par (13.27, 14.92 and 14.31% for chlorantraniliprole 18.5 SC, cyantraniliprole 10OD and flubendiamide 480SC respectively) and also on par with, emamectin benzoate 5SG (14.85%) and spinosad 45SC (15.82%). Azadirachtin 300 ppm was found next best treatment (18.22%) and found significantly superior to seedling dipping method. Dipping method was found significantly inferior to foliar spray and soil drenching (21.34, 23.92 and 22.95% for chlorantraniliprole 18.5 SC, flubendiamide 480SC and cyantraniliprole 10OD respectively).

Mean of two applications with respect to per cent reduction in fruit damage over control revealed the superiority of foliar application of diamides like chlorantraniliprole 18.5 SC, flubendiamide 480SC and cyantraniliprole 10OD recorded 64.18, 61.29 and 61.08 per cent reduction respectively. This was followed by soil drenching of chlorantraniliprole 18.5 SC (56.32), soil drenching of flubendiamide 480SC (53.11), soil drenching of cyantraniliprole 10OD (51.00), emamectin benzoate 5SG (50.33), spinosad 45SC (47.59), azadirachtin 300 ppm (39.99), seedling dipping of chlorantraniliprole 18.5 SC (31.60), seedling dipping of flubendiamide 480SC (26.00) and seedling dipping of cyantraniliprole 10 OD (22.48) (Fig 1).

Among the three methods of application of diamides through foliar spray was found to be best method followed by soil drenching. Seedling dipping method performed poor.

Shoot and fruit damage mirrored in yield of brinjal fruits. The data on the effect of different insecticides on yield of brinjal are presented in Table 3. Significant differences were found among various treatments with respect to yield of brinjal. Diamides were found significantly superior to other treatments. Among the diamides chlorantraniliprole 18.5 SC applied as foliar spray recorded highest yield of 47.80 t/ha with the gross and net returns (Rs.14,34,000 and 11,98,410) with highest C:B ratio of chlorantraniliprole 18.5 SC @0.5ml/l (1:6.09 (Table 3).

It was found that, chlorantraniliprole and cyantraniliprole act for the same binding site, on the other hand, flubendiamide and ryanodine increase the sensitivity of the receptor to chlorantraniliprole Thus, hypothetically the anthranilic diamides, phthalic acid diamides and ryanodine bind to different, but somehow, related sites (ISAACS *et al*., 2012). This may be attributed differential effects of these diamides against the pest.

Diamides are recently introduced broad spectrum insecticides which act as ryanodine receptor modulators. They belong to 28th main group of IRAC mode of classification. Anthranilic diamides are derived from alkaloid isolated from a plant *Ryania speciosa* (Vahl). Pthalic diamide is a chemical derivate group developed by Nihon nohyaku co. ltd (Tokyo japan). Insecticides of this group bind to the ryanodine receptors in insect muscle cells, depletes the intracellular calcium stores leading to paralysis and cessation of feeding and mortality after 1-3 days. It has ovicidal and ovo- larvicidal action. Because of translaminar and systemic action, they can be applied as foliar and also as soil application. This new group of insecticides are effective at low rates or doses, high level of selectivity, greater specificity to target pests along with low toxicity to non- target organisms and environment and has replaced many conventional compounds (Satpathy*et al*., 2020).

Husheeth*et al*. (2015) reported that, diamides are an alternative to pyrethroids for the management of *O. nubilalis* in snap bean and adoption of diamides by snap bean growers could improve the efficiency of production by reducing the number of sprays required each season.

The first commercialized diamide, chlorantraniliprole, has exceptional activity against lepidopteran pests. The second anthranilamide product, cyantraniliprole has excellent cross-spectrum activity against a range of insect orders, including both lepidopteran and hemipteran pests (Selby *et al*., 2016).

Bhuvaneshwari *et al.* (2022) reported that diamides because of the relatively low risk to non-target organisms and environment, high target specificity and their versatility in application methods, these important classes of new insecticides play a greater role in the present context of environmental safety and their consequent uses in integrated pest management and insect resistance management programmes.

Diamides delivered to vegetable crops via seed, in-furrow, or foliar treatments; therefore, it would be desirable to provide high levels of pest control while minimizing the amount of active ingredient. It would be less disruptive to disturb naturally occurring biological control organisms and to protect pollinators by using anthranilic diamides instead of broader spectrum insecticides. As time passes, the value of these benefits will increase by loss of registrations or problems with insect resistance of conventional insecticides. Exploring for newly developed materials with multiple application techniques are necessary for fostering innovation (Rebecca *et al*., 2016)

Seedling dipping with diamides was found inferior compare to foliar spray and soil drenching. It might be due to reduced concentration of over a period of time. However, the method was given protection against *L. orbonalis* and other defoliators which was very much evident from the observations of these pests much earlier in the plots where diamides are delivered through foliar spray and soil drenching.

Chlorantraniliprole is xylem mobile and moves throughout the green tissue of plants. While the primary function of xylem is to transport water and minerals from roots to aerial plant parts and these insecticide solution moves through xylem. Young leaves have high amount of insecticide residues compare to matured parts. Similarly, cyantraniliprole and flubendiamide moves in same fashion but its penetrating power and spreading capabibilty of active ingredient varies (Zhang *et al*., 2022)

Cyantraniliprole is also xylem mobile since phloem mobility is absent, xylem flux was the predominant driving force that distributed cyantraniliprole throughout the plant system being quickly absorbed by roots and transported acropetally via the evapotranspiration stream in xylem. Cyantraniliprole was also detected in all plant tissues at all sampling intervals up to fruit maturity with residue concentrations declining in the order of foliage>fowers>fruits. Accordingly, the higher residue concentrations in mature leaves compared with other tissues may be explained by the relative position and flow velocity for each respective plant tissues within the evapotranspiration stream. Young leaves and flowers located in the positions of the farthest upward-transport along the xylem flux from soil pore water to plant apex. On the other hand, relative surface area of tomato leaves and fruits suggested that the xylem flux for leaves to be signifcantly larger than for fruits. From 7 – 28 days after transplanting high residues of cyantraniliprole was found in mature leaves compare to young leaves. After 28 days after transplanting the residues decrease in mature leaves with slight decrease in young leaves. At 84 DAT, low residues in mature leaves and high residues in young leaves were observed, flower exhibited high residues at 21 days after transplanting and decreased at 49 days after transplanting. In fruits, cyantraniliprole residue decreased with sampling intervals from its highest concentration at the immature green stage 42 Days after transplanting to its lowest at the red ripening stage 84 days after transplanting (Huynah*et al*., 2021).

These findings can be correlated with superiority of foliar spray over soil drenching and seedling dipping. The translocation of diamides in corn plants could enhance the control of *Spodoptera frugiperda (*Smith) based on their application form. Chlorantraniliprole and cyantraniliprole were applied *via* seed treatment and foliar spray revealed that, the translocation of chlorantraniliprole and cyantraniliprole from sprayed leaves to new leaves was not observed. An increased dosage of cyantraniliprole and chlorantraniliprole did not influence on its translocation in plant tissues, however, it influenced on the present amount of active ingredient, regardless of the stage of application. The application of chlorantraniliprole and cyantraniliprole in seed treatment is an important alternative for integrated pest management. The absorption and redistribution capacity of chlorantraniliprole and cyantraniliprole throughout the plant confer a prolonged residual action with satisfactory control of *S. frugiperda*(Pes *et al.,* 2020).

Flubendiamide under field conditions degrades to des-iodo flubendiamide and it also degrades very slowly. Volatilization from soil and water surface is not expected to be an important dissipation route. In anaerobic aquatic conditions, flubendiamide transforms mainly to des-iodo flubendiamide (DT50 of 137 days in the water/sediment system), with this not undergoing any further degradation (Das *et al.*, 2017).

Higher efficacy of diamides may be attributed to depletion of intracellular calcium stores from the muscle cells of insects, causing impaired muscle regulation, paralysis and ultimately death. This novel molecule with unique mode of action is a best component in integrated pest management which is helpful for the farmers and a valuable option for insecticide resistance management strategies. The efficacy of cyantraniliprole and flubendiamide may be due to impairing function. It also leads to feeding cessation, uncoordinated movements, partial paralysis, uncontrolled regurgitation in lepidopteran insects. Due to unique chemical structure and novel modes of action with translaminar action these diamides shows excellent control of pest populations resistant to other conventional insecticides.

The present findings are in accordance with Latif *et al*. (2009) who reported that flubendiamide 480 SC was found to reduce fruit and shoot infestation in addition to mechanical control, potash, and field sanitation. Jagginavar *et al*. (2009) reported that chlorantraniliprole 18.5SC and flubendiamide 480SC were found to be effective in controlling shoot and fruit borer. Hannig *et al* (2009) determined that, in addition to the acute effects of muscle dysfunction and paralysis, chlorantraniliprole quickly suppresses pest feeding, which reduces damage. Kodandaram *et al.* (2010) reported that superiority of chlorantraniliprole is because of its translaminar and systemic action, can be applied as foliar spray and as soil application. It is found to be safe to parasitods, predators and pollinators.

Among different delivery methods foliar spray was found highly effective compare to soil drenching and seedling dipping. It might be attributed to immediate coverage and contact activity on entire plant system and the pest. Whenever foliar spray is given insecticide enters the leaves through stomata and reaches xylem vessels, penetrates rapidly into tissues and thus protect the entire leaf and finally reaches different plant parts as a quick process. Whereas in soil drenching, it is comparatively a slow process and similarly seedling dipping. The time needed between root uptake and effective control should be carefully considered.

Kameshwaran *et al*. (2015) reported that, the treatment with chlorantraniliprole 18.5 SC SC @ 40 g a.i./ha recorded the lowest mean per cent shoot damage, which was followed by emamectin benzoate 25 WG @ 11 g a.i./ha. And when compared to the untreated control (14.20 t/ha), the maximum yield was seen in the treatment with chlorantraniliprole 20 SC @ 40 g a.i./ha (27.08 t/ha) followed by emamectin benzoate 25 WG @ 11 g a.i./ha (23.61 t/ha). Younas *et al*. (2016) revealed that foliar applications of both chlorantraniliprole and cyantraniliprole had demonstrated their efficacy against several pests, including *S. frugiperda*, egg plant fruit and shoot borer, *Leucinodes orbonalis* (Guenee), codling moth, *Cydiapomonella* (L.), *B. tabaci*, European corn borer, *Ostrinianubilalis* (Hubner) and *H. armigera*. Kushwaha *et al*. (2016) reported the less incidence of shoot, fruit infestation and good B:C ratio with chlorantraniliprole 18.5 SC (2.98%, 3.266% and 1:5.48) followed by flubendiamide (3.06%, 3.560% and 1:4.91) spinosad (4.59%, 4.103% and 1:.4.65). It can be a part of integrated pest management under chemical control. Shridhara *et al*. (2019) reported that, chlorantraniliprole 18.5SC, flubendiamide 480SC and emamectin benzoate 5 SG was found to be superior in increasing yield by controlling shoot and fruit infestation.

Rebecca *et al.* (2016) foliar spray applications of both diamides (chlorantraniliprole and cyantranilprole) consistently achieved superior *O. nubilalis*control compared with the seed and in-furrow applications in snap bean.

Due to unique chemical structure and novel modes of action with translaminar action these diamides shows excellent control of pest populations resistant to other conventional insecticides. As all the conventional insecticides act on nervous system these diamides act mainly on muscle system. These diamides products are remarkably potent with insect pests, they work on insects' resistance to other chemistries, they have great rotational partners with other products. We are now in the era of diamides because of unique mode of action and safety to predators, parasitoids, environment with low mammalian toxicity. Many vegetable insect pests are managed using neonicotinoid and pyrethroid insecticides. Unfortunately, these insecticides are toxic to many bees and natural enemies and no longer control and some pests that have developed resistance. Anthranilic diamide insecticides provide systemic control of many herbivorous arthropod pests, but exhibit low toxicity to beneficial arthropods and mammals and may be a promising alternative to neonicotinoids and pyrethroids.

4. **Conclusion:**

In conclusion, the application of an anthranilic diamide at planting has both economic and environmental benefits for commercial vegetable production. Growers could reduce the number of insecticide applications needed to control key insect pests by making a single application at planting, thereby reducing the amount of labour, fuel, and other costs associated with foliar pesticide applications. A seedling dipping option would be ideal because it requires no additional resources at planting and further minimizes contact by the applicator. The substitution of anthranilic diamides in place of broader spectrum insecticides would reduce the disruption of naturally occurring biological control organisms and conserve pollinators. These advantages will be increasingly important as older materials lose registrations or experience pest resistance issues. Exploring multiple methods of application for newly developed materials is critical for developing innovative pest management programs that require minimal pesticide use.

Table 1. Efficacy of diamides delivered through different methods on shoot damage and fruit damageby*Leucinodes orbonalis* (Guenee)

Trt No.	Treatment details	Dose (g/ml)	**Per cent shoot damage (*First application)	**Per cent shoot damage (*Second application)	Mean of two applications	**Per cent fruit damage (*First application)	**Per cent fruit damage (*Second application)	Mean of two applications
1	Chlorantraniliprole 18.SC (Foliar spray)	0.3	11.95 (20.22) ^{a}	11.89 (20.17) ^{a}	11.92 (20.20) ^{a}	10.76 (19.15) ^{ab}	10.45 (18.86) ^{a}	10.60 (19.00) ^{a}
2	Chlorantraniliprole18.5 SC (Soil drenching)	0.3	13.16 (21.27) ^{a}	15.56 (23.23) ^{b}	14.36 (22.27) ^{a}	12.10 (20.35) ^{abc}	14.45 (22.34) ^{b}	13.27 (21.37) ^{b}
3	Chlorantraniliprole 18.5SC (Seedling dipping)	0.3	20.34 (26.81) ^{ef}	24.78 (29.85)^{d}	22.56 (28.36) ^{d}	17.32 (24.59)^{fg}	25.36 (30.24) ^{d}	21.34 (27.51) ^{d}
4	Cyantraniliprole 10 OD (Foliar spray)	0.3	13.07 (21.19) ^{a}	14.39 (22.29) ^{a}	13.73 (21.75) ^{a}	11.14 (19.49)^{ab}	11.85 (20.14) ^{a}	11.54 (19.82) ^{a}
5	Cyantraniliprole 10 OD (Soil drenching)	0.3	16.02 (23.59) ^{bc}	17.86 (25.00) ^{b}	16.94 (24.30) ^{b}	13.49 (21.55)^{cd}	16.35 (23.85) ^{b}	14.92 (22.72) ^{b}
6	Cyantraniliprole 10 OD (Seedling dipping)	0.3	22.06 (28.01) ^{fg}	26.75 (31.14) ^{d}	24.40 (29.60) ^{d}	20.40 (26.85)^{h}	27.45 (31.60) ^{d}	23.92 (29.28) ^{d}
7	Flubendiamide 480 SC (Foliar spray)	0.3	12.61 (20.80) ^{a}	13.45 (21.51) ^{a}	13.03 (21.16) ^{a}	11.53 (19.85)^{abc}	11.46 (19.79) ^{a}	11.49 (19.82) ^{a}
8	Flubendiamide 480 SC (Soil drenching)	0.3	14.07 (22.03) ^{ab}	15.78 (23.41) ^{b}	14.92 (22.73) ^{b}	12.82 (20.98)^{bcd}	15.79 (23.41) ^{b}	14.31 (22.22) ^{b}
9	Flubendiamide 480 SC	0.3	21.76	25.78	23.77	19.13	26.78	22.95

	(Seedling dipping)		(27.81)[efg]	(30.51) [d]	(29.18) [d]	(25.93)[gh]	(31.16) [d]	(28.63) [d]
10	Chlorantraniliprole 18.5 SC (Standard Check)	0.5	11.76 (20.06) [a]	11.24 (19.59) [a]	11.50 (19.83) [a]	10.44 (18.85) [a]	10.23 (18.65) [a]	10.34 (18.75) [a]
11	Emamectin Benzoate 5 SG (Standard check)	0.2	16.01 (24.01) [bc]	17.89 (25.02) [b]	17.23 (24.52) [b]	14.48 (22.36) [de]	15.23 (22.97) [b]	14.85 (22.67) [b]
12	Azadirachtin 300 ppm (Standard check)	5	19.58 (26.26) [de]	20.33 (26.80) [c]	19.96 (26.53) [c]	16.67 (24.10) [ef]	19.78 (26.41) [c]	18.22 (25.27) [c]
13	Spinosad 45 SC	0.1	17.74 (24.91) [cd]	18.77 (25.67) [b]	18.25 (25.29) [c]	14.85 (22.67) [de]	16.78 (24.18) [b]	15.82 (23.43) [b]
14	UTC		23.92 (29.28) [g]	45.78 (42.58) [e]	34.85 (36.18) [e]	23.71 (29.14) [i]	39.78 (39.10) [e]	31.74 (34.29) [e]
	C.D (0.05%)		2.36	3.35	3.17	2.26	3.11	2.88
	F. value		7.46	9.87	6.78	5.07	7.41	8.42
	P. value		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Figures in parentheses are arc sine transformed values. Means followed by the same letter are not significantly different by DMRT. * Soil drenching and foliar spray. ** 7 days after treatment.

Table 2. Per cent reduction over control of shoot damage and fruit damage by *Leucinodes orbonalis* (Guenee)

Tr. No.	Application methods	Dose (g/ml)	Per cent reduction over control		Mean of two applications	Per cent reduction over control		Mean of two applications
			*First Application	*SecondApplication		*First Application	*SecondApplication	
1	Chlorantraniliprole 18.5 SC (Foliar spray)	0.3	50.05	74.03	62.04	54.62	73.73	64.18
2	Chlorantraniliprole18.5 SC (Soil drenching)	0.3	44.97	66.01	56.63	48.97	63.68	56.32
3	Chlorantraniliprole 18.5 SC (Seedling dipping)	0.3	14.96	45.87	30.42	26.95	36.25	31.60
4	Cyantraniliprole 10 OD (Foliar spray)	0.3	45.36	68.57	56.96	53.03	70.21	61.08
5	Cyantraniliprole 10 OD (Soil drenching)	0.3	33.03	60.99	47.01	43.11	58.90	51.00
6	Cyantraniliprole 10 OD (Seedling dipping)	0.3	7.77	41.57	24.67	13.97	31.00	22.48
7	Flubendiamide 480 SC (Foliar spray)	0.3	47.27	70.62	58.95	51.38	71.19	61.29
8	Flubendiamide 480 SC (Soil drenching)	0.3	41.16	65.53	53.35	45.91	60.31	53.11

9	Flubendiamide 480 SC (Seedling dipping)	0.3	9.01	43.69	26.35	19.32	32.68	26.00
10	Chlorantraniliprole 18.5 SC (Standard Check)	0.5	50.80	75.45	63.13	55.96	74.28	65.12
11	Emamectin Benzoate 5 SG (Standard check)	0.2	30.75	60.92	45.83	38.94	61.71	50.33
12	Azadirachtin (Neem) 300 ppm (Standard check)	5	18.13	55.59	36.86	29.69	50.28	39.09
13	Spinosad 45 SC	0.1	25.83	59.00	42.42	37.36	57.82	47.59
14	Untreated control	0.0	0	0	0	0.00	0.00	0.00

* Soil drenching
Foliar spray

Table 3: Yield and CB ratio

Tr. No.	Treatments	Dose	Yield (t\ha)	Cost of pest management (Rs)	Cost of cultivation (Rs)	Total COC (Rs)	Gross returns (Rs)	Net returns (Rs)	C:B ratio
T1	Chlorantraniliprole 18.5 SC F.S	0.3ml	47.80 [a]	3090	232500	235590	1434000	1198410	6.07
T2	Chlorantraniliprole 18.5 SC	0.3ml	45.70 [b]	11906	232500	244406	1371000	1126594	5.61
T3	Chlorantraniliprole 18.5 SC	0.3ml	38.40 [d]	1583	232500	234083	1152000	917917	4.92
T4	Cyantraniliprole 10 OD	0.3ml	46.80 [a]	1691	232500	234191	1404000	1169809	6.00
T5	Cyantraniliprole 10 OD	0.3ml	44.50 [b]	6089	232500	238589	1335000	1096411	5.48
T6	Cyantraniliprole 10 OD	0.3ml	36.40 [d]	940	232500	233440	1092000	858560	4.68
T7	Flubendamide 480 SC	0.3ml	47.20 [a]	3300	232500	235800	1416000	1180200	6.01
T8	FLubendamide480 SC	0.3ml	45.10 [b]	12780	232500	245280	1353000	1107720	5.52
T9	Flubendiamide 480 SC	0.3ml	38.10 [d]	1680	232500	234180	1143000	908820	4.88
T10	Chlorantraniliprole 18.5 SC	0.5ml	48.20 [a]	4950	232500	237450	1446000	1208550	6.09
T11	Emamectin benzoate 5 SG	0.2g	42.10 [c]	950	232500	233450	1263000	1029550	5.41
T12	Azadirachtin 300ppm	5 ml	40.10 [c]	1550	232500	234050	1203000	968950	5.14
T13	Spinosad 45 S.C	0.1ml	41.30 [c]	1600	232500	234100	1239000	1004900	5.29
T14	Control	0.3ml	22.70 [e]	0	232500	232500	681000	448500	2.93
	SEm±		0.67						
	C.D (0.05%)		2.01						

T1, T4, T7 – Foliar spray; T2, T5, T8 – Soil drenching; T3, T6, T9 – Seedling dipping; T10, T11, T12 – Standard checks. COC – Cost of cultivation. Means followed by the same letter are not significantly different by DMRT.

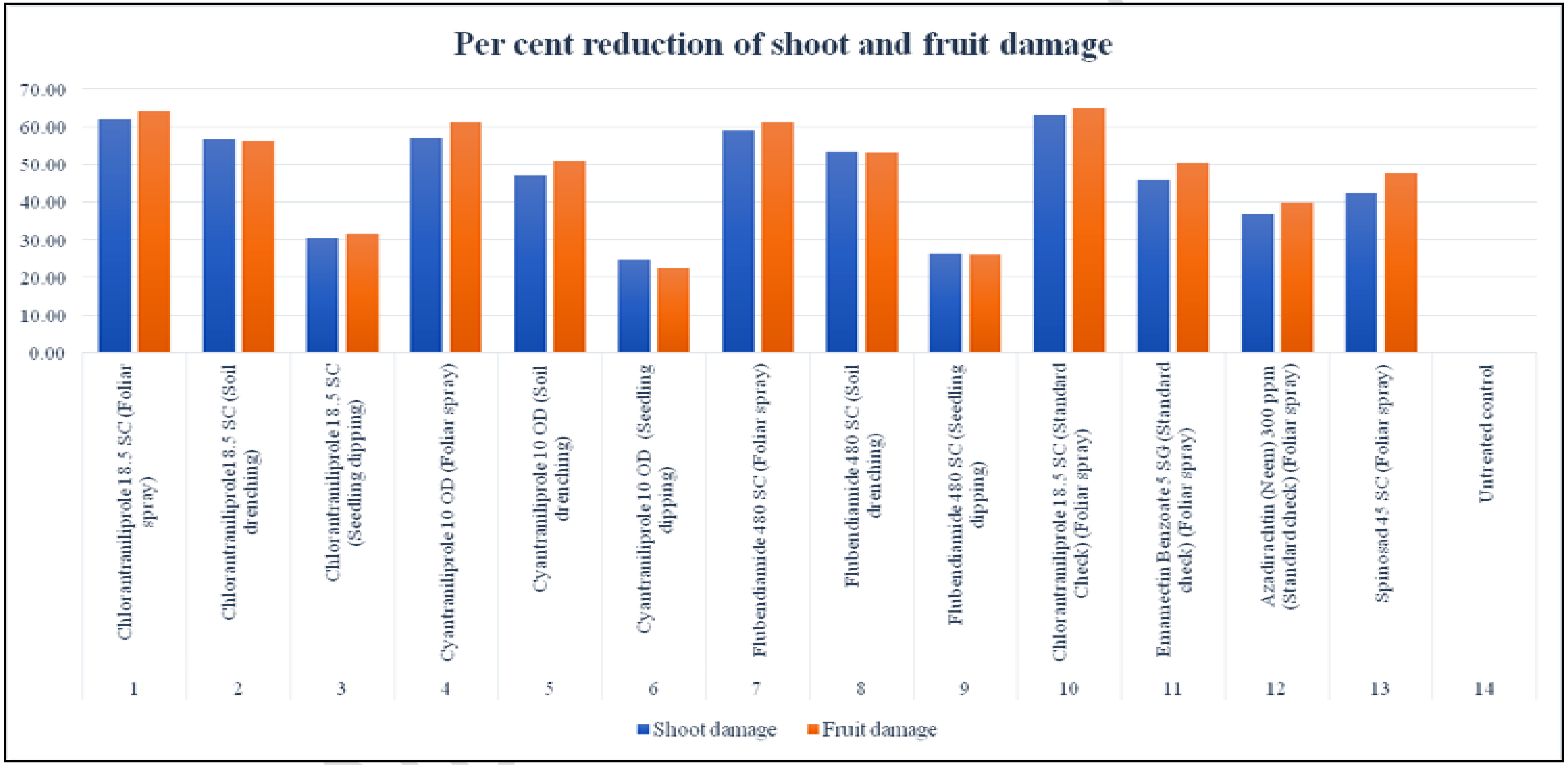

Fig 1. **Per cent reduction of shoot and fruit damage across different treatments**

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