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Bio-efficacy of Newer Insecticides against Leafhopper (*Empoasca flavescens)* of Castor (*Ricinus communis* Linneaus)

D.M. Chaudhary*, P.S. Patel, D.H. Padhiyar, M.K. Chandaragi, P.K. Thakar and C.S. Barad
Department of Agricultural Entomology, C.P. College of Agriculture,
S.D. Agricultural University, Sardarkrushinagar-385 506 (Gujarat), India.

(Corresponding author: D.M. Chaudhary)*
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ABSTRACT: Given the substantial role of leafhoppers (*E. flavescens*) in causing large-scale grain yield losses, the present field experiments on bio-efficacy of newer insecticides against leafhopper of castor (*Ricinus communis* Linnaeus) were carried out on Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar during *kharif*, 2021-22 and 2022-23, aiming to provide valuable insights into their effectiveness in managing leafhoppers and addressing the challenges associated with pest-induced losses in castor cultivation. Among the various insecticides tested, flonicamid 50 WG was found the most effective insecticide against leafhopper. Highest (1:21.56) protection cost: benefit ratio obtained when castor plots was treated with flonicamid 50 WG.

Keywords: Castor, newer insecticides, bio-efficacy, leafhopper.

INTRODUCTION

Castor bean (*Ricinus communis* Linnaeus) is an important non-edible oil crop belonging to the Euphorbiaceae family. Castor is native to the southeastern Mediterranean basin, East Africa and India. Currently, castor is grown on an industrial scale in about 30 countries. India, particularly Gujarat, is the world's largest producer of castor beans, with a production of 1235.07 M.T. in an area of 8.63 lakh ha and an average productivity of 1767.00 kg/ha (Anon., 2021). Gujarat alone covers 6.07 lakh ha, contributing significantly to the country's total production with an annual yield of 1235.07 M.T. and a productivity of 2033.00 kg/ha. One of the main constraints that limit the productivity of hops is excessive damage caused by sucking pests. Yield losses of 12.4 to 15 percent have been reported due to sucking pests in Gujarat (Khanpara and Patel 2002). Flonicamid, fipronil, spinosad and dinotefuran are new molecules with novel mode of action and efficacy against sucking insect pests in various crop ecosystems (Babu *et al.*, 2012; Pachundkar *et al.*, 2013; Chaudhari *et al.*, 2015; Chandi *et al.*, 2016). Leafhoppers (*E. flavescens*) played a significant role in large-scale grain yield losses. Therefore, this study was conducted to determine the field efficacy of these newer insecticides in the treatment of grasshoppers.

MATERIAL AND METHODS

With a view to evaluate the bio-efficacy of newer insecticides against leafhopper on castor, a field experiment was conducted following Randomized Block Design with seven treatments and three replications at Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *kharif*, 2021-22 and 2022-23. The plot having uniform size (Gross: 6 m × 7.2 m and Net: 3 m × 4.8 m), with a spacing of 150 cm × 120 cm were selected and used for the study.

Different insecticides were applied at appropriate rates using a knapsack sprayer. The first insecticide treatment application was made with the highest leafhopper population stage occurring in the field. The second spraying was given at a fifteen-day interval after the first spraying. Five plants were selected at random from the net plot per replication and tagged with labels leaving the border rows. The leafhopper population was recorded on three leaves in each plant, i.e. one leaf each from the upper, middle and lower part of the plant. The recording of observations on leafhopper occurred at one day before, as well as 3, 7, 10, and 14 days after spraying. Subsequently, the mean population per plant was calculated for each treatment. Yield of castor from the net plot was recorded and weighted with the help of electronic weighing balance and converted in to kg/ha. The data, thus, obtained were subjected to statistical analysis for drawing meaningful conclusion.

RESULTS AND DISCUSSION

The results on leafhopper population before and after spray are presented and discussed here as under.

Efficacy against leafhopper (*E. flavescens*)

First year (2021-22). The population of leafhopper was homogenous before spray in all the treatments as treatments did not differ significantly. All the evaluated insecticides were significantly superior over control up to 14 days of spray.

First spray

Three days after spray. Following the initial spray, the plots treated with flonicamid 50 WG exhibited the lowest leafhopper population at 2.67 leafhoppers per leaf, comparable to spinosad 45 SC (3.08 leafhoppers/leaf) and fipronil 5 SC (3.80 leafhoppers/leaf) after three days (Table 1). Thiamethoxam 25 WG (4.32 leafhoppers/leaf) and diafenthiuron 50 WP (5.18 leafhoppers/leaf) were subsequently identified as effective treatments, showing similar results. Dinotefuron 20 SG displayed an observed population of 5.95 leafhoppers per leaf among the evaluated insecticides. The untreated plot exhibited the highest population at 9.66 leafhoppers per leaf.

Seven days after spray. The plots treated with flonicamid 50 WG exhibited the minimum leafhopper population at 1.91 leafhoppers per leaf, comparable to spinosad 45 SC at 2.34 leafhoppers per leaf. Following these, fipronil 5 SC (3.34 leafhoppers/leaf) and thiamethoxam 25 WG (3.58 leafhoppers/leaf) were identified as effective treatments, significantly impacting the pest population. The subsequent effective treatments were dinotefuron 20 SG (5.02 leafhoppers/leaf), on par with diafenthiuron 50 WP (4.62 leafhoppers/leaf). The untreated plot displayed the highest population at 9.93 leafhoppers per leaf.

Ten days after spray. Data recorded on ten days after spraying depicts thatflonicamid 50 WG was found significantly most effective which showed lowest 2.09 leafhoppers per leaf, which was at par with spinosad 45 SC (2.68 leafhoppers/leaf). The treatments fipronil 5 SC and thiamethoxam 25 WG were found to be the next best treatments which were statistically at par with each other as they recorded 3.59 and 3.95 leafhoppers per leaf. Next effective treatments dinotefuron 20 SG (5.40 leafhoppers/leaf) and it was at par with diafenthiuron 50 WP (4.94 leafhoppers/leaf).

Fourteen days after spray. fourteen days after first spray, flonicamid 50 WG showed the lowest (2.39 leafhoppers/leaf) population of leafhopper and it was at par with spinosad 45 SC (2.96 leafhoppers/leaf). Next effective treatments fipronil 5 SC (3.86 leafhoppers/leaf) population of hopper and it was at par with thiamethoxam 25 WG (4.44 leafhoppers/leaf) followed by dinotefuron 20 SG (5.52 leafhoppers/leaf) and it was at par with diafenthiuron 50 WP (5.28 leafhoppers/leaf).

The mean results of pooled over period after first spray (Table 1) showed that the flonicamid 50 WG lowest incidence of hopper (2.26 leafhoppers/leaf) and found to be superior among all other tested insecticides. It was found at par with spinosad 45 SC (2.76 leafhoppers/leaf) and fipronil 5 SC (3.64 leafhoppers/leaf). Thiamethoxam 25 was found to be mediocre in its effectiveness and recorded 4.07 leafhoppers per leaf. Whereas, diafenthiuron 50 WP (5.00 leafhoppers/leaf) and dinotefuron 20 SG (5.47 leafhoppers/leaf) were found least effective. The maximum population was observed in untreated plot (10.01 leafhoppers/leaf).

Second spray

Three days after spray. The lowest (1.24 leafhoppers/leaf) population of leafhopper was recorded from flonicamid 50 WG which was at par with spinosad 45 SC (2.11 leafhoppers/leaf) at three days after second spray (Table 1). The next effective treatments were fipronil 5 SC (2.96 leafhoppers/leaf) and thiamethoxam 25 WG (3.64 leafhoppers/leaf) which was at par with each other. Followed by (4.78 leafhoppers/leaf) population of leafhopper was recorded dinotefuron 20 SG and it was at par with diafenthiuron 50 WP (4.34 leafhoppers/leaf). The maximum population was observed in untreated plot (11.4 leafhoppers/leaf).

Seven days after spray. Flonicamid 50 WG maintained its superiority, demonstrating the lowest leafhopper population at 0.75 leafhoppers per leaf, followed by spinosad 45 SC at 1.45 leafhoppers per leaf, with statistical parity between the two. The subsequent top-performing treatments were fipronil 5 SC at 2.24 leafhoppers per leaf, on par with thiamethoxam 25 WG at 2.90 leafhoppers per leaf. Diafenthiuron 50 WP recorded a population of 3.66 leafhoppers per leaf, and dinotefuron 20 SG followed closely at 4.23 leafhoppers per leaf.

Ten days after spray. Second spray of insecticides indicated that flonicamid 50 WG was found significantly most effective 0.56 leafhoppers per leaf, which was at par with Spinosad 45 SC (0.86 leafhoppers/leaf). The treatments fipronil 5 SC and thiamethoxam 25 WG were found to be the next best treatments which were statistically at par with each other as they recorded 1.80 and 2.49 leafhoppers per leaf. Dinotefuron 20 SG was recorded (3.72 leafhoppers/leaf) it was at par with diafenthiuron 50 WP (3.28 leafhoppers/leaf).

Fourteen days after spray. Flonicamid 50 WG and spinosad 45 SC demonstrated significant superiority, recording 1.13 and 1.87 leafhoppers per leaf, respectively. The subsequent effective treatments included fipronil 5 SC at 2.79 leafhoppers per leaf and thiamethoxam 25 WG at 3.35 leafhoppers per leaf. Dinotefuron 20 SG recorded a leafhopper population of 4.32 per leaf, while diafenthiuron 50 WP registered 3.75 leafhoppers per leaf, both being statistically at par.

The mean results pooled over the period after the second spray (Table 1) revealed that flonicamid 50 WG exhibited the lowest incidence of leafhoppers at 0.90 leafhoppers per leaf, statistically comparable to spinosad 45 SC, which recorded 1.54 leafhoppers per leaf. Fipronil 5 SC and thiamethoxam 25 WG emerged as the next best treatments, both statistically on par with each other, recording 2.43 and 3.08 leafhoppers per leaf, respectively. Diafenthiuron 50 WP and dinotefuron 20 SG recorded 3.75 and 4.26 leafhoppers per leaf, respectively.

Second year (2022-23). The population of leafhopper was homogenous before spray in all the treatments as treatments did not differ significantly. All the evaluated insecticides were significantly superior over control up to 14 days of spray.

First spray

Three Days after spray. The minimum leafhopper population, at 2.58 leafhoppers per leaf, was observed with the application of flonicamid 50 WG, a statistically equivalent result to the treatment with spinosad 45 SC, which exhibited 3.29 leafhoppers per leaf. Following these, the next effective treatments were fipronil 5 SC and thiamethoxam 25 WG, recording populations of 3.68 and 4.45 leafhoppers per leaf, respectively. Lastly, dinotefuron 20 SG registered 6.43 leafhoppers per leaf, statistically comparable to diafenthiuron 50 WP, which recorded 5.66 leafhoppers per leaf.

Seven days after spray. The minimum leafhopper population (1.89 leafhoppers/leaf) was recorded of flonicamid 50 WG it was at par with spinosad 45 SC (2.61 leafhoppers/leaf). The treatment of fipronil 5 SC and thiamethoxam 25 WG were found to be the next best treatments which were statistically at par with each other as they recorded 3.63 and 3.98 leafhoppers per leaf, respectively. Dinotefuron 20 SG was recorded (6.01 leafhoppers/leaf) population and it was at par with diafenthiuron 50 (5.41 leafhoppers/leaf).

Table 1: Bio-efficacy of different insecticides against castor leafhopper during 2021-22.

Trt. No.	Treatments	Concentration (%)	Leafhoppers/leaf											
			DBS	First spray				Pooled over period	Second spray				Pooled over period	Pooled over period over spray
				3 DAS	7 DAS	10 DAS	14 DAS		3 DAS	7 DAS	10 DAS	14 DAS		
T_1	Fipronil 5 SC	0.005	2.97 (8.30)	2.07^{abc} (3.80)	1.96^{bc} (3.34)	2.02^{bc} (3.59)	2.09^{bc} (3.86)	2.03^{bc} (3.64)	1.86^{bc} (2.96)	1.65^{bc} (2.24)	1.52^{b} (1.80)	1.81^{bc} (2.79)	1.71^{bc} (2.43)	1.87^{bc} (3.01)
T_2	Thiamethoxam 25WG	0.008	2.90 (7.92)	2.19^{bcd} (4.32)	2.02^{c} (3.58)	2.11^{cd} (3.95)	2.22^{cd} (4.44)	2.14^{cd} (4.07)	2.03^{cd} (3.64)	1.84^{cd} (2.90)	1.73^{bc} (2.49)	1.96^{cd} (3.35)	1.89^{cd} (3.08)	2.01^{cd} (3.56)
T_3	Dinotefuron 20 SG	0.008	3.11 (9.17)	2.54^{d} (5.95)	2.35^{d} (5.02)	2.43^{e} (5.40)	2.45^{d} (5.52)	2.44^{d} (5.47)	2.30^{d} (4.78)	2.18^{e} (4.23)	2.05^{d} (3.72)	2.19^{d} (4.32)	2.18^{d} (4.26)	2.31^{d} (4.85)
T_4	Spinosad 45 SC	0.0135	3.08 (8.99)	1.89^{ab} (3.08)	1.69^{ab} (2.34)	1.78^{ab} (2.68)	1.86^{ab} (2.96)	1.81^{ab} (2.76)	1.62^{ab} (2.11)	1.40^{ab} (1.45)	1.16^{a} (0.86)	1.54^{ab} (1.87)	1.43^{ab} (1.54)	1.62^{ab} (2.12)
T_5	Diafenthiuron 50 WP	0.06	3.08 (9.00)	2.38^{cd} (5.18)	2.26^{cd} (4.62)	2.33^{de} (4.94)	2.40^{cd} (5.28)	2.34^{cd} (5.00)	2.20^{d} (4.34)	2.04^{de} (3.66)	1.95^{cd} (3.28)	2.06^{cd} (3.75)	2.06^{d} (3.75)	2.20^{d} (4.35)
T_6	Flonicamid 50WG	0.015	3.13 (9.30)	1.78^{a} (2.67)	1.55^{a} (1.91)	1.61^{a} (2.09)	1.70^{a} (2.39)	1.66^{a} (2.26)	1.32^{a} (1.24)	1.12^{a} (0.75)	1.03^{a} (0.56)	1.28^{a} (1.13)	1.18^{a} (0.90)	1.42^{a} (1.52)
T_7	Untreated control	-	3.07 (8.92)	3.19^{e} (9.66)	3.23^{e} (9.93)	3.27^{f} (10.21)	3.32^{e} (10.54)	3.24^{e} (10.01)	3.45^{e} (11.4)	3.49^{f} (11.68)	3.62^{e} (12.59)	3.74^{e} (13.48)	3.57^{e} (12.27)	3.41^{e} (11.11)
S.Em.±	T		0.18	0.11	0.10	0.09	0.10	0.05	0.10	0.10	0.09	0.11	0.05	0.04
	P		-	-	-	-	-	0.04	-	-	-	-	0.04	0.03
	S		-	-	-	-	-	-	-	-	-	-	-	0.02
	T × P		-	-	-	-	-	0.10	-	-	-	-	0.10	0.08
	S × P		-	-	-	-	-	-	-	-	-	-	-	0.04
	S × T		-	-	-	-	-	-	-	-	-	-	-	0.05
	S × P × T		-	-	-	-	-	-	-	-	-	-	-	0.11
C.D. at 5%			N.S.	0.33	0.29	0.29	0.31	0.28	0.30	0.29	0.27	0.33	0.28	0.11
C.V.%			10.18	8.17	7.71	7.36	7.58	7.69	7.99	8.44	8.14	8.90	8.38	9.63

DBS- Day before spray; DAS-Day after spray;

*Figures in parentheses are indicates retransformed values of square root transformation; Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance.

Ten Days after spray. The lowest (2.23 leafhoppers/leaf) population recorded flonicamid 50 WG and it was at par with spinosad 45 SC (2.97 leafhoppers/leaf). Followed by fipronil 5 SC (3.75 leafhoppers/leaf) and thiamethoxam 25 WG (4.44 leafhoppers/leaf) also recorded lower population of leafhopper. Next effective treatments (6.24 leafhoppers/leaf) population of leafhopper was recorded dinotefuron 20 SG and it was at par with diafenthiuron 50 WP (5.65 leafhoppers/leaf).

Fourteen days after spray. Flonicamid 50 WG demonstrated the lowest leafhopper population at 2.52 leafhoppers per leaf, statistically comparable to spinosad 45 SC at 3.27 leafhoppers per leaf. Among the tested insecticides, fipronil 5 SC (4.20 leafhoppers/leaf) and thiamethoxam 25 WG (4.95 leafhoppers/leaf) recorded lower leafhopper populations. Plots treated with dinotefuron 20 SG registered 6.37 leafhoppers per leaf, with statistical parity with diafenthiuron 50 WP, which recorded 6.01 leafhoppers per leaf.

Analyzing the pooled data over the period after the first spray (Table 2), flonicamid 50 WG emerged as highly superior among all treated insecticides, recording 2.30 leafhoppers per leaf. Spinosad 45 SC followed closely at 3.03 leafhoppers per leaf, with statistical parity. The next best treatments were fipronil 5 SC (3.81 leafhoppers/leaf), at par with thiamethoxam 25 WG (4.45 leafhoppers/leaf). Diafenthiuron 50 WP (5.67 leafhoppers/leaf) and dinotefuron 20 SG (6.26 leafhoppers/leaf) were also effective. The untreated plot exhibited the highest population at 11.52 leafhoppers per leaf.

Second spray

Three days after spray. Lowest leafhopper population (1.43 leafhoppers/leaf) was recorded by flonicamid 50 WG. It was at par with spinosad 45 SC by exhibiting 2.45 leafhoppers per leaf. The next effective treatments were fipronil 5 SC and thiamethoxam 25 WG against leafhopper by recording population 3.21 and 4.14 leafhoppers per leaf. Dinotefuron 20 SG were recorded 5.73 leafhoppers per leaf and it was at par with diafenthiuron 50 WP (5.08 leafhoppers/leaf).

Seven days after spray. The minimum hopper population, at 0.90 leafhoppers per leaf, was recorded with flonicamid 50 WG, which was statistically equivalent to spinosad 45 SC at 1.64 leafhoppers per leaf. Among the tested insecticides, fipronil 5 SC (2.32 leafhoppers/leaf) and thiamethoxam 25 WG (3.23 leafhoppers/leaf) exhibited lower populations. Plots treated with dinotefuron 20 SG recorded 5.02 leafhoppers per leaf, statistically comparable to diafenthiuron 50 WP, which recorded 4.23 leafhoppers per leaf.

Table 2: Bio-efficacy of different insecticides against castor leafhopper during 2022-23.

Tr. No.	Treatments	Concentration (%)	Leafhoppers/leaf											
			DBS	First spray				Pooled over period	Second spray				Pooled over period	Pooled over period over spray
				3 DAS	7 DAS	10 DAS	14 DAS		3 DAS	7 DAS	10 DAS	14 DAS		
T_1	**Fipronil 5 SC**	0.005	2.94 (8.15)	2.05^{ab} (3.68)	2.03^{b} (3.63)	2.06^{bc} (3.75)	2.17^{bc} (4.20)	2.08^{b} (3.81)	1.93^{bc} (3.21)	1.68^{bc} (2.32)	1.62^{b} (2.13)	1.89^{bc} (3.07)	1.78^{bc} (2.66)	1.93^{bc} (3.22)
T_2	**Thiamethoxam 25WG**	0.008	2.92 (8.02)	2.23^{bc} (4.45)	2.12^{bc} (3.98)	2.22^{cd} (4.44)	2.34^{cd} (4.95)	2.23^{bc} (4.45)	2.15^{cd} (4.14)	1.93^{cd} (3.23)	1.86^{bc} (2.95)	2.07^{cd} (3.79)	2.00^{cd} (3.51)	2.11^{cd} (3.97)
T_3	**Dinotefuron 20 SG**	0.008	3.21 (9.79)	2.63^{d} (6.43)	2.55^{d} (6.01)	2.60^{e} (6.24)	2.62^{d} (6.37)	2.60^{c} (6.26)	2.50^{d} (5.73)	2.35^{e} (5.02)	2.21^{d} (4.38)	2.34^{d} (4.99)	2.35^{d} (5.02)	2.47^{e} (5.62)
T_4	**Spinosad 45 SC**	0.025	3.27 (10.19)	1.95^{ab} (3.29)	1.76^{ab} (2.61)	1.86^{ab} (2.97)	1.94^{ab} (3.27)	1.88^{ab} (3.03)	1.72^{ab} (2.45)	1.46^{ab} (1.64)	1.23^{a} (1.01)	1.62^{ab} (2.14)	1.51^{ab} (1.77)	1.69^{ab} (2.37)
T_5	**Diafenthiuron 50 WP**	0.06	3.23 (9.91)	2.48^{cd} (5.66)	2.43^{cd} (5.41)	2.48^{de} (5.65)	2.55^{cd} (6.01)	2.48^{c} (5.67)	2.36^{d} (5.08)	2.17^{de} (4.23)	2.10^{cd} (3.90)	2.19^{cd} (4.30)	2.21^{de} (4.37)	2.35^{de} (5.00)
T_6	**Flonicamid 50WG**	0.015	3.21 (9.83)	1.75^{a} (2.58)	1.55^{a} (1.89)	1.65^{a} (2.23)	1.74^{a} (2.52)	1.67^{a} (2.30)	1.39^{a} (1.43)	1.18^{a} (0.90)	1.08^{a} (0.67)	1.32^{a} (1.24)	1.24^{a} (1.04)	1.46^{a} (1.63)
T_7	**Untreated control**	-	3.13 (9.33)	3.40^{e} (11.06)	3.47^{e} (11.52)	3.48^{f} (11.64)	3.51^{e} (11.82)	3.47^{d} (11.52)	3.57^{e} (12.28)	3.66^{f} (12.87)	3.63^{e} (12.71)	3.52^{e} (11.86)	3.59^{f} (12.41)	3.53^{f} (11.96)
S.Em.±	**T**		0.18	0.12	0.11	0.11	0.12	0.06	0.11	0.10	0.09	0.10	0.05	0.05
	P		-	-	-	-	-	0.04	-	-	-	-	0.04	0.04
	S		-	-	-	-	-	-	-	-	-	-	-	0.03
	T × P		-	-	-	-	-	0.12	-	-	-	-	0.10	0.11
	S × P		-	-	-	-	-	-	-	-	-	-	-	0.06
	S × T		-	-	-	-	-	-	-	-	-	-	-	0.08
	S × P × T		-	-	-	-	-	-	-	-	-	-	-	0.16
C.D. at 5%			N.S.	0.38	0.33	0.35	0.37	0.33	0.35	0.31	0.28	0.30	0.29	0.16
C.V.%			10.12	8.97	8.13	8.37	8.53	8.50	8.82	8.49	7.98	7.91	8.36	12.97

DBS- Day before spray; DAS-Day after spray;
*Figures in parentheses are indicates retransformed values of square root transformation; Treatment means with the letter(s) in common are not significant by DNMRT at5% level of significance.

Ten days after spray. The lowest (0.67 leafhoppers/leaf) population recorded flonicamid 50 WG and it was at par with spinosad 45 SC (1.01 leafhoppers/leaf).The followed by next treatments with fipronil 5 SC (2.13 leafhoppers/leaf) and thiamethoxam 25 WG (2.95 leafhoppers/leaf) also recorded lower population. The (4.38 leafhoppers/leaf) population was recorded dinotefuron 20 SG and it was at par with diafenthiuron 50 WP (3.90 leafhoppers/leaf).

Fourteen days after spray. The flonicamid 50 WG was found to be most effective which showed lowest 1.24 leafhoppers per leaf, it was statistically at par with spinosad 45 SC (2.14 leafhoppers/leaf). The treatments fipronil 5 SC and thiamethoxam 25 WG were found to be the next best treatments it was at par with each other as they recorded 3.07 and 3.79 leafhoppers per leaf, respectively. The treatments diafenthiuron 50 WP (4.30 leafhoppers/leaf) and dinotefuron 20 SG (4.99 leafhoppers/leaf).

In the pooled data over the period after the second spray (Table 2), flonicamid 50 WG emerged as highly superior among all treated insecticides, recording 1.04 leafhoppers per leaf. Spinosad 45 SC followed closely at 1.77 leafhoppers per leaf, with statistical parity. The next best treatment was fipronil 5 SC (2.66 leafhoppers/leaf), on par with thiamethoxam 25 WG (3.51 leafhoppers/leaf). Diafenthiuron 50 WP recorded 4.37 leafhoppers per leaf, and dinotefuron 20 SG registered 5.02 leafhoppers per leaf. The untreated plot exhibited the highest population at 12.41 leafhoppers per leaf.

Table 3: Bio-efficacy of different insecticides against castor leafhopper (Pooled over year).

Tr. No.	Treatments	Concentration (%)	Leafhoppers/leaf		
			2021-22	2022-23	Pooled over year
T_1	**Fipronil5 SC**	0.005	1.87^{bc}(3.01)	1.93^{bc}(3.22)	1.90^{bc}(3.11)
T_2	**Thiamethoxam25WG**	0.008	2.01^{cd}(3.56)	2.11^{cd}(3.97)	2.06^{cd}(3.76)
T_3	**Dinotefuron20 SG**	0.008	2.31^{d}(4.85)	2.47^{e}(5.62)	2.39^{e}(5.23)
T_4	**Spinosad45 SC**	0.0135	1.62^{ab}(2.12)	1.69^{ab}(2.37)	1.66^{ab}(2.24)
T_5	**Diafenthiuron50 WP**	0.06	2.20^{d}(4.35)	2.35^{de}(5.00)	2.27^{de}(4.67)
T_6	**Flonicamid50WG**	0.015	1.42^{a}(1.52)	1.46^{a}(1.63)	1.44^{a}(1.57)
T_7	**Untreated control**	-	3.41^{e}(11.11)	3.53^{f}(11.96)	3.47^{f}(11.53)
S.Em.±			0.04	0.05	0.03
		P	0.03	0.04	0.02
		S	0.02	0.03	0.01
		Y	-	-	0.01
		T × P	0.08	0.11	0.07
		S × P	0.04	0.06	0.03
		S × T	0.05	0.08	0.05
		Y × P	-	-	0.03
		Y × T	-	-	0.05
		Y × S	-	-	0.02
		S × P × T	0.11	0.16	0.10
		Y × S × T	-	-	0.07
		Y × S × P	-	-	0.05
		Y × P × T	-	-	0.10
		Y × S × P × T	-	-	0.14
C.D. at 5%			0.11	0.16	0.10
C.V. %			9.63	12.97	11.50

The results of pooled over year of first and second year (Table 3) indicated that flonicamid 50 WG (1.57 leafhoppers/leaf) was found significantly superior than all the insecticides except spinosad45 SC (2.24 leafhoppers/leaf) it was statistically at par with each other. The treatments fipronil 5 SC and thiamethoxam 25 WG were recorded next treatments which were at par with each other as they recorded 3.11 and 3.76 leafhoppers per leaf, respectively. Lastly, dinotefuron 20 SG was recorded 5.23 leafhoppers per leaf and it was statistically at par with diafenthiuron 50 WP (4.67 leafhoppers/leaf). The highest population was observed in untreated plot (11.53 leafhoppers/leaf).

This are agreement with the works of Gaurkhede *et al.* (2015) suggested of flonicamid was significantly superior. Nemade *et al.* (2017) concluded that newer molecule flonicamid was found promising to managed sucking pests of *Bt.* cotton followed by buprofezin and diafenthiuron. Meghana *et al.* (2018) revealed that the flonicamid was significantly superior insecticide in minimizing the leafhopper population followed by dinotefuran, diafenthiuron, acetamiprid, thiamethoxam and fipronil compared to untreated control. However, Singh *et al.* (2020) revealed that the flonicamid was significantly superior in suppressing population of leafhopper population.

Effect on castor yield. The pooled data of two years was presented in Table 4 revealed that significantly higher (2975 kg/ha) yield of castor was obtained with treatment of spinosad 45 SC it was remained at par with fipronil 5 SC (2947 kg/ha).

Table 4: Impact of different insecticidal treatments on yield of castor.

Tr. No.	Treatments	Conc.	Yield (kg/ha)		
			2021-22	2022-23	Pooled
T_1	Fipronil5 SC	0.005	2958[ab]	2937[a]	2947[a]
T_2	Thiamethoxam25WG	0.008	2796[abc]	2777[ab]	2786[b]
T_3	Dinotefuron20 SG	0.008	2691[bc]	2669[b]	2680[bc]
T_4	Spinosad45 SC	0.0135	2985[a]	2966[a]	2975[a]
T_5	Diafenthiuron50 WP	0.06	2618[c]	2598[b]	2608[c]
T_6	Flonicamid50WG	0.015	2813[abc]	2791[ab]	2802[b]
T_7	Untreated control	-	1708[d]	1716[c]	1711[d]
S.Em.±		T	80.86	76.66	43.68
		Y	-	-	23.35
		T × Y	-	-	61.78
C.D. at 5%			249.15	236.21	179.98
C.V.%			8.19	7.95	7.04

The plots treated with flonicamid 50 WG obtained 2802 kilogram per hectare it was remained at par with thiamethoxam 25 WG (2786 kg/ha) and dinotefuron 20 SG 2680 kg/ha) followed by diafenthiuron 50 WP (2608 kg/ha). The lowest (1711 kg/ha) castor yield was obtained in control plots. These findings are in accordance with Nemade *et al.* (2017) evaluate the highest seed cotton yield (1681.02 Kg/ha.) was obtained from flonicamid 50% WG @ 75 g a.i./ha followed by flonicamid 50% WG @ 100 g a.i./ha (1627.31 kg/ha).

Increase in yield over control. The pooled data on increase in yield over control are presented in Table 5 indicated that the yield of castor increased over control ranged from 73.82 to 52.35 per cent. The descending order of castor yield increase over control was spinosad45 SC (73.82%) >fipronil 5 SC (72.19%) > flonicamid 50 WG (63.69%) >thiamethoxam 25 WG (62.78%) > dinotefuron 20 SG (56.56%) >diafenthiuron 50 WP (52.35%).

Avoidable loss in yield. The pooled data on avoidable losses in yield was ranged from 0.94 to 42.47 per cent. The avoidable losses in castor yield were minimum in thefipronil 5 SC (0.94%) followed by flonicamid 50 WG (5.83%). On the other hand, the highest avoidable loss in castor yield was in control (42.47%).

The ascending order of avoidable loss of remaining treatments were thiamethoxam 25 WG (6.35%) < dinotefuron 20 SG (9.93%) <diafenthiuron 50 WP (12.35%).

Protection cost: benefit ratio (PCBR). The protection cost: benefit ratio of the different treatments are worked out from the pooled yield data of 2021-22 and 2022-23 presented in Table 6. Considering the economics of treatments, highest (1:21.56) protection cost benefit ratio obtained when castor plots was treated with flonicamid 50 WG which was followed by thiamethoxam 25 WG in which PCBR recorded 1:19.45. The lowest (1:10.58) PCBR was recorded in the treatments of diafenthiuron 50 WP. On the basis of PCBR the different treatments were arranged in the following descending order *i.e.,* flonicamid 50 WG cent (1:21.56) >thiamethoxam 25 WG (1:19.45) >fipronil 5 SC (1:19.10) >spinosad 45 SC (1:11.00) > dinotefuron 20 SG (1:10.58).

Table 5: Effect of various insecticides on increase in yield over control and avoidable loss in castor.

Tr. No.	Treatments	Conc.	Increase in yield over control (%)			Avoidable loss (%)		
			2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	Fipronil5 SC	0.005	73.22	71.15	72.19	0.90	0.98	0.94
T_2	Thiamethoxam25WG	0.008	63.73	61.83	62.78	6.33	6.37	6.35
T_3	Dinotefuron20 SG	0.008	57.59	55.54	56.56	9.85	10.01	9.93
T_4	Spinosad45 SC	0.0135	74.80	72.84	73.82	-	-	-
T_5	Diafenthiuron 50 WP	0.06	53.31	51.40	52.35	12.29	12.41	12.35
T_6	Flonicamid50WG	0.015	64.73	62.65	63.69	5.76	5.90	5.83
T_7	Untreated Control	-	-	-	-	42.79	42.14	42.47

Table 6: Economics of various insecticides evaluated against leafhopper of castor.

Tr. No.	Treatments	Quantity of insecticides required for two sprays (L/ha)	Cost of insecticides (₹/ha)	Cost of labour (₹/ha)	Total cost (v/ha)	Yield (kg/ha)	Gross realization (₹/ha)	Net realization (₹/ha)	Net profit (₹/ha)	PCBR
T_1	Fipronil 5 SC	1	1560	2130	3690	2947	176820	74160	70470	19.10
T_2	Thiamethoxam 25WG	0.32	1024	2130	3154	2786	167160	64500	61346	19.45
T_3	Dinotefuron 20 SG	0.40	2716	2130	4846	2680	160800	58140	53294	11.00
T_4	Spinosad 45 SC	0.30	2864	2130	4994	2975	178500	75840	70846	14.19
T_5	Diafenthiuron 50 WP	1.20	2516	2130	4646	2608	156480	53820	49174	10.58
T_6	Flonicamid 50WG	0.30	772	2130	2902	2802	168120	65460	62558	21.56
T_7	Untreated control	-	-	-	-	1711	102660	-	-	-

Price of castor : ₹60/ kg; **Labour charges** : ₹355/labour/day (3 labours per hectare required for one spray); **Water requirement** : 500 Litre/ha

Flonicamid 50 WG- ₹2575/kg
Thiamethoxam 25 WG - ₹3200/kg
Fipronil 5 SC- ₹1560/l
Dinotefuran 20 SG - ₹6973/kg
Spinosad 45 SC - ₹9547/l
Diafenthiuron 50 WP - ₹2097/kg

CONCLUSIONS

Based on the findings of the current investigation, the newer insecticides, specifically flonicamid 50 WG and spinosad 45 SC, demonstrated superior efficacy compared to the standard insecticides currently recommended for managing leafhoppers in the castor ecosystem. The highest protection cost: benefit ratio (1:21.56) was achieved when castor plots were treated with flonicamid 50 WG.

FUTURE SCOPE

The findings of this study on the field efficacy of newer insecticides against leafhoppers in castor cultivation can contribute to the development of robust, sustainable and economically viable pest management strategies for castor cultivation, benefiting both farmers and the environment.

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