International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(7): 546-553
www.biochemjournal.com
Received: 13-05-2024
Accepted: 16-06-2024

Dr. Meeral D Suthar
Department of Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Dr. CB Varma
Department of Agricultural Entomology, College of Agriculture, Anand Agricultural University, Vaso, Gujarat, India

Dr. PK Borad
Department of Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Dr. Meeral D Suthar
Department of Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Evaluation of insecticides against leaf eating caterpillar in drumstick

Dr. Meeral D Suthar, Dr. CB Varma and Dr. PK Borad

DOI: https://doi.org/10.33545/26174693.2024.v8.i7Sg.1574

Abstract
Leaf eating caterpillar is major pest of drumstick causing significant damage to the plantations. Farmers are spraying pesticides to manage this pest by their own experience. As of now none of the insecticides is registered in CIBRC for managing this pest in drumstick. An experiment was conducted at a farmer`s field to evaluate the efficacy of insecticides against leaf eating caterpillar in drumstick. Treatments of chlorantraniliprole 18.5% SC 0.0075%, chlorantraniliprole 18.5% SC 0.006%, emamectin benzoate 5% SG 0.0024% and emamectin benzoate 5% SG 0.0019% were found effective and economical in managing leaf eating caterpillar in drumstick.

Keywords: Leaf eating caterpillar, *Noorda* spp., efficacy, insecticides

Introduction
Drumstick, *Moringa oleifera* Lamarck is an important vegetable crop rich in minerals and vitamins. It belongs to the family Moringaceae, which is a family consisting of only one genus with about 13 species of deciduous trees (Keay, 1989) [6]. India is the largest producer of moringa with an area of 93,917 acres and production of 1,30,00,00 tonne (https://discuss.farmnest.com/t/drumstick-cultivation-guide/22197). In the last few years, the tree has attracted farmers in Gujarat for its low establishment, maintenance and operational costs. However, due to low awareness regarding the package of practices, and various biotic and abiotic stresses farmers are not able to harvest cent per cent benefit from it. There are number of biotic stresses of *M. oleifera* in its native Indian range, which affects its production from both qualitative and quantitative aspects. Infestations by insect pests and mites have been placed among the main limiting factors. Such an important vegetable crop has been devasted by twenty-eight different insect species and two species of mites are damaging to this crop in India. Among them, aphid, *Aphis craccivora* Koach, *Aphis gossypii* Glover (Aphididae: Hemiptera); whitefly, *Trialeurodes rara* Singh, *Aleurodicus dispersus* Russel (Aleyrodidae: Hemiptera); thrips, *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae); moringa budworm: *Noorda moringae* Tams (Crambidae: Lepidoptera); green leaf caterpillar, *Noorda blitealis* Walker (Crambidae: Lepidoptera) and hairy caterpillar, *Eupterote mollifera* Walker (Eupterotidae: Lepidoptera) are of major importance. Thumar *et al.* (2017) [11] reported leaf eating caterpillar caused damage to leaves as well as the bud of drumstick from middle Gujarat. Farmers are also going for fortnight application of insecticides for the management of this lepidopteran pest. The literature on insect pests of moringa and their management is scanty. Moreover, none of the insecticides are recommended for use in moringa by the Central Insecticide Board though, many synthetic insecticides have been used by farmers for the control of various pests their toxic residues can created many repercussions as this crop has high medicinal value. Therefore, an experiment was carried out to help farmers be aware of which insect pests are causing damage to moringa and at what stage as well as how to manage them effectively and economically.

Materials and Methods
The existing drumstick (Var. PKM-1) orchard was selected at farmer`s field for the experiment. The required trees having equal growth, age and canopy were selected. The experiment was laid out in a Complete Randomized Design with three repetitions.

The recommended practices except pest control were followed during experimentation. There were total eight treatments *viz.*, Chlorantraniliprole 18.5% SC, 0.0045%, 22.50 g a.i./ha, 2.25 ml/10 lit. of water; Chlorantraniliprole 18.5% SC, 0.006%, 30.00 g a.i./ha, 3.00 ml/10 lit. of water; Chlorantraniliprole 18.5% SC, 0.0075%, 37.50 g a.i./ha, 3.75 ml/10 lit. of water; Emamectin benzoate 5% SG, 0.0014% 7.13 g a.i./ha, 2.85 g/10 lit. of water; Emamectin benzoate 5% SG,0.0019%, 9.50 g a.i./ha, 3.80 g/10 lit. of water; Emamectin benzoate 5% SG, 0.0024%, 11.88 g a.i./ha, 4.75 g/10 lit. of water; Quinalphos 25% EC, 0.05%, 250.00 g a.i./ha, 20.00 ml/10 lit. of water (chemical check) and control. The first spray was given at the initiation of the pest. The second spray was given after 15 days of the first spray. Spray fluid was applied to the extent of slight runoff using a foot sprayer with triple triple-action nozzle. For recording observations, one tree was considered as one repetition. From each tree, four branches were selected from each direction. From each branch, five shoots each of 15 cm were selected randomly and damaged shoots were counted. The larval population was also recorded from the same selected shoot. The observations were recorded one day before the first spray and subsequently at 5, 10 and 15 days after each spray. Populations of natural enemies were recorded from each selected shoot of tree. Visual observations on phytotoxicity parameters *viz.*, leaf injury on tip/surface, wilting, vein clearing, necrosis, epinasty, hyponasty etc. At 5, 10 and 15 day(s) of each spray were recorded for all the treatments (based on 1-10 scale: 1: 0-10%, 2: 11-20%, 3: 21-30%, 4: 31-40%, 5: 41-50%, 6: 51-60%, 7: 61-70%, 8: 71-80%, 9: 81-90% and 10: 91-100%).

Results and Discussion

Larval population

First year (Table 1)

First spray

The data of larval population before spay indicated that the incidence of leaf eating caterpillar was uniform as the difference among the treatments was non-significant. The results on pooled over the first spray indicated that the lowest (1.96) number of larvae were found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (2.12), chlorantraniliprole 18.5% SC, 0.006% (2.19) and emamectin benzoate 5% SG, 0.0019% (2.26). The next effective group based on larval population was chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% which recorded larval population between 3.07 and 3.54 per 5 shoots.

Second spray

Data of pooled over the second spray revealed that all the treatments were found significantly superior to the control. The lowest (0.91) number of larvae was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (1.13), chlorantraniliprole 18.5% SC, 0.006% (1.21) and emamectin benzoate 5% SG, 0.0019% (1.21). Chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% emerged as the next best effective group of treatments.

Pooled over sprays: In case of pooled over sprays, the lowest (1.40) larval population was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (1.60), chlorantraniliprole 18.5% SC, 0.006% (1.69) and emamectin benzoate 5% SG, 0.0019% (1.72). Trees treated with chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% recorded larval population between 2.53 and 3.15 per 5 shoots.

Second year (Table 2)

First spray

During the second year, the results on pooled over the first spray indicated that the lowest (1.69) number of larvae were found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (1.87), chlorantraniliprole 18.5% SC, 0.006% (1.96) and emamectin benzoate 5% SG, 0.0019% (2.02). The next effective group based on larval population was chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% which recorded population between 2.81 and 3.30 per 5 shoots.

Second spray

Data of pooled over the second spray showed that all the treatments were found significantly superior to the control. The lowest (0.84) number of larvae was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (0.98), emamectin benzoate 5% SG, 0.0019% (1.08) and chlorantraniliprole 18.5% SC, 0.006% (1.11). Chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% emerged out as the next best effective group of treatments by recording larval population between 1.96 and 2.66 per 5 shoots.

Pooled over sprays

Results of pooled over sprays exhibited that the lowest (1.24) number of larvae were found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (1.40), chlorantraniliprole 18.5% SC, 0.006% (1.51) and emamectin benzoate 5% SG, 0.0019% (1.54). The remaining treatments showed a more or less similar trend of effectiveness as noticed in the first year.

Pooled over years (Table 3)

Results of pooled over years exhibited that the lowest (1.32) number of larvae were found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with emamectin benzoate 5% SG, 0.0024% (1.49), chlorantraniliprole 18.5% SC, 0.006% (1.57) and emamectin benzoate 5% SG, 0.0019% (1.60).

Shoot damage

First year (Table 4)

First spray

Damage caused by leaf eating caterpillars was found uniform in all the trees before the application of insecticides. Even after 5 days after application, the difference was non-significant. The results of pooled over the first spray indicated that the lowest (62.27%) damage was found in trees treated with chlorantraniliprole 18.5% SC, 0,0075%

and it was at par with emamectin benzoate 5% SG, 0.0024 (66.97%), chlorantraniliprole 18.5% SC, 0.006 (64.10%) and emamectin benzoate 5% SG, 0.0019 (67.08%). The next effective group based on damage was chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% which recorded damage between 78.61 and 86.16 per cent.

Second spray

In case of pool over second spray, the lowest (43.06%) damage was recorded in trees treated with chlorantraniliprole 18.5% SC, 0,0075% and it was at par with chlorantraniliprole 18.5% SC, 0.006% (45.45%), emamectin benzoate 5% SG, 0.0019 (46.48%) and emamectin benzoate 5% SG, 0.0024% (50.05%). Of the evaluated insecticides, the highest (70.23%) damage was noticed in trees treated with quinalphos 25% EC, 0.05% and it was at par with emamectin benzoate 5% SG, 0.0014 (63.88%) and chlorantraniliprole 18.5% SC, 0.0045% (62.13%).

Pooled over sprays

Of the evaluated insecticides, the lowest (52.72%) damage was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with chlorantraniliprole 18.5% SC, 0.006% (54.86%), emamectin benzoate 5% SG, 0.0019% (56.92%) and emamectin benzoate 5% SG, 0.0024 (58.65%). Chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% emerged out as the next best effective group of treatments by recording damage between 70.72 and 78.74 per cent.

Second year (Table 5)

First spray

The results of pooled over first spray indicated that the lowest (57.24%) damage was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with chlorantraniliprole 18.5% SC, 0.006% (59.01%), emamectin benzoate 5% SG, 0.0024% (60.16%) and emamectin benzoate 5% SG, 0.0019% (61.93%). The next effective group based on damage was chlorantraniliprole 18.5% SC, 0.0045%, emamectin benzoate 5% SG, 0.0014% and quinalphos 25% EC, 0.05% which recorded damage between 73.52 and 80.93 per cent.

Second spray

In case of pool over second spray, the lowest (37.95%) damage was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with chlorantraniliprole 18.5% SC, 0.006% (40.27%), emamectin benzoate 5% SG, 0.0024% (41.40%) and emamectin benzoate 5% SG, 0.0019% (44.77%). Among the tested insecticides, the highest (64.95%) damage was found in trees treated with quinalphos 25% EC, 0.05% and it was at par with emamectin benzoate 5% SG, 0.0014 (58.60%) and chlorantraniliprole 18.5% SC, 0.0045% (56.23%).

Pooled over sprays

The lowest (47.54%) damage was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with chlorantraniliprole 18.5% SC, 0.006% (49.63%), emamectin benzoate 5% SG, 0.0024% (50.79%) and emamectin benzoate 5% SG, 0.0019% (53.40%). Of the evaluated insecticides, the highest (73.33%) damage was noticed in trees treated with quinalphos 25% EC, 0.05% followed by emamectin benzoate 5% SG, 0.0014 (58.60%) and chlorantraniliprole 18.5% SC, 0.0045% (56.23%).

Pooled over years (Table 6)

The lowest (50.12%) damage was found in trees treated with chlorantraniliprole 18.5% SC, 0.0075% and it was at par with chlorantraniliprole 18.5% SC, 0.006% (52.25%). However, later one was found at par with emamectin benzoate 5% SG, 0.0024% (54.72%) and emamectin benzoate 5% SG, 0.0019% (55.16%). Among the evaluated insecticides, the highest (76.08%) damage was noticed in trees treated with quinalphos 25% EC, 0.05% followed by emamectin benzoate 5% SG, 0.0014 (69.92%) chlorantraniliprole 18.5% SC, 0.0045% (67.95%).

Natural enemies (Table 7-9)

The population of spiders was uniform in all the treatments before spray as the treatment difference was non-significant. The population of spiders recorded at 5, 10 and 15 days after the first and second sprays were found non-significant in both the years as well as in pooled over years. The analysis of periodical data indicated that all the insecticidal treatments were found more or less equally safer to this predator.

Phytotoxicity

There were no any kind of phytotoxic symptoms observed during experimentation.

Economics (Table 10)

The cost of the two applications was 7669 and 5002 Rs./ha for effective treatments chlorantraniliprole 18.5% SC, 0.006% and emamectin benzoate 5% SG, 0.0019%, respectively. The remaining treatments cost 8915 to 3772 Rs./ha for two applications.

Discussion

Patel and Borad (2016) [8] reported chlorantraniliprole 20 SC, 0.006 per cent as an effective insecticide against capsule borer in castor. Chlorantraniliprole resulted in greater mortality of *Helicoverpa zea* in soybean (Adams *et al.*, 2016) [1]. Ghidiu *et al.* (2009) [5] reported that two applications of chlorantraniliprole through drip irrigation resulted in season-long control of European corn borer, *Ostrinia nubialis* (Hübner), in bell peppers, *Capsicum annuum* (L). According to Su *et al.* (2017), chlorantraniliprole was significantly more effective than emamectin benzoate against *Pieris rapae* in cabbage. Carscallen *et al.* (2019) [3] stated that chlorantraniliprole offers a potential alternative to conventionally used insecticides in the management of *Mythimna unipuncta* in corn. Chlorantraniliprole and emamectin benzoate exhibited high levels of toxicity to *H. armigera* moths with a mortality of 86.67% and 91.11%, respectively (Liu *et al.*, 2017) [7]. Venkataiah *et al.* (2015) [12] proved chlorantraniliprole 18.5 SC more effective insecticide against *Spodoptera litura* in groundnut. Chlorantraniliprole provides consistent protection from defoliation to soybean crop from *Spodoptera litura* and *Chrysodeixis acuta* (Patil *et al.*, 2014) [9]. According to Gadhiya *et al.* (2014) [4], chlorantraniliprole (0.006%) and emamectin benzoate (0.002%) were more effective in protecting the groundnut crop from the infestation of *Helicoverpa armigera* and *Spodoptera litura*. Chlorantraniliprole application in open field conditions was found to be harmless to natural enemy (coccinellids and spiders) in cotton ecosystem (Anuradha *et al.*, 2023) [2].

Table 1: Bioefficacy of insecticides on leaf eating caterpillar infesting drumstick during 2018

Sr. No.	Insecticides	Conc. (%)	No. of larva (e)/ 5 shoots days after spray									Pooled over sprays
			First					Second				
			Before spray	5	10	15	Pooled	5	10	15	Pooled	
1	Chlorantraniliprole 18.5% SC	0.0045	2.12^{a} (3.99)	1.88^{ab} (3.03)	1.86^{b} (2.96)	1.93^{bc} (3.22)	1.89^{b} (3.07)	1.77^{b} (2.63)	1.63^{bc} (2.16)	1.38^{bc} (1.40)	1.60^{c} (2.06)	1.74^{c} (2.53)
2	Chlorantraniliprole 18.5% SC	0.006	2.05^{a} (3.70)	1.75^{ab} (2.56)	1.53^{a} (1.84)	1.65^{a} (2.22)	1.64^{a} (2.19)	1.46^{a} (1.63)	1.32^{ab} (1.24)	1.15^{ab} (0.82)	1.31^{d} (1.21)	1.48^{b} (1.69)
3	Chlorantraniliprole 18.5% SC	0.0075	2.09^{a} (3.87)	1.71^{a} (2.42)	1.41^{a} (1.49)	1.58^{a} (2.00)	1.57^{a} (1.96)	1.38^{a} (1.40)	1.19^{a} (0.92)	1.01^{a} (0.52)	1.19^{d} (0.91)	1.38^{a} (1.40)
4	Emamectin benzoate 5% SG	0.0014	2.10^{a} (3.91)	1.87^{ab} (3.00)	1.91^{b} (3.15)	1.98^{cd} (3.42)	1.92^{b} (3.19)	1.83^{b} (2.85)	1.68^{c} (2.32)	1.44^{c} (1.57)	1.65^{bc} (2.22)	1.78^{c} (2.67)
5	Emamectin benzoate 5% SG	0.0019	2.10^{a} (3.91)	1.78^{ab} (2.67)	1.55^{a} (1.90)	1.66^{ab} (2.26)	1.66^{a} (2.26)	1.47^{a} (1.66)	1.34^{ab} (1.30)	1.12^{a} (0.75)	1.31^{d} (1.21)	1.49^{b} (1.72)
6	Emamectin benzoate 5% SG	0.0024	2.06^{a} (3.74)	1.72^{ab} (2.46)	1.50^{a} (1.75)	1.63^{a} (2.16)	1.62^{a} (2.12)	1.44^{a} (1.57)	1.28^{a} (1.14)	1.11^{a} (0.73)	1.28^{d} (1.13)	1.45^{ab} (1.60)
7	Quinalphos 25% EC	0.05	2.08^{a} (3.83)	1.85^{ab} (2.92)	2.06^{bc} (3.74)	2.12^{cd} (3.99)	2.01^{bc} (3.54)	1.98^{bc} (3.42)	1.83^{c} (2.85)	1.63^{c} (2.15)	1.81^{b} (2.77)	1.91^{d} (3.15)
8	Control	--	2.15^{a} (4.12)	2.08^{b} (3.83)	2.16^{c} (4.17)	2.22^{d} (4.43)	2.15^{c} (4.12)	2.16^{c} (4.17)	2.20^{d} (4.34)	2.18^{d} (4.25)	2.18^{a} (4.25)	2.17^{e} (4.21)
	S. Em. ±	Treatment (T)	0.10	0.10	0.07	0.08	0.05	0.08	0.09	0.07	0.05	0.03
		Period (P)	--	--	--	--	0.03	--	--	--	0.03	0.02
		T X P	--	--	--	--	0.08	--	--	--	0.08	0.06
	C.V.%		8.92	10.06	6.69	7.81	8.35	8.75	10.75	9.44	9.68	8.96

Notes:
1. Figures in parenthesis are retransformed values; those outside are $\sqrt{x+0.5}$ transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance
3. Significant parameters and their interaction: S, P, S X P, T, S X T
4. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 2: Bioefficacy of insecticides on leaf eating caterpillar infesting drumstick during 2019

Sr. No.	Insecticides	Conc. (%)	No. of larva (e)/ 5 shoots days after spray									Pooled over sprays
			First					Second				
			Before spray	5	10	15	Pooled	5	10	15	Pooled	
1	Chlorantraniliprole 18.5% SC	0.0045	2.05^{a} (3.70)	1.81^{ab} (2.78)	1.79^{b} (2.70)	1.86^{bc} (2.95)	1.82^{b} (2.81)	1.73^{b} (2.49)	1.61^{b} (2.09)	1.38^{b} (1.40)	1.57^{b} (1.96)	1.70^{c} (2.39)
2	Chlorantraniliprole 18.5% SC	0.006	1.98^{a} (3.42)	1.68^{ab} (2.32)	1.44^{a} (1.57)	1.57^{a} (1.96)	1.57^{a} (1.96)	1.40^{a} (1.46)	1.29^{a} (1.16)	1.11^{a} (0.73)	1.27^{a} (1.11)	1.42^{b} (1.51)
3	Chlorantraniliprole 18.5% SC	0.0075	2.03^{a} (3.62)	1.63^{a} (2.16)	1.32^{a} (1.24)	1.50^{a} (1.75)	1.48^{a} (1.69)	1.32^{a} (1.24)	1.15^{a} (0.82)	1.00^{a} (0.50)	1.16^{a} (0.84)	1.32^{a} (1.24)
4	Emamectin benzoate 5% SG	0.0014	2.03^{a} (3.62)	1.80^{ab} (2.74)	1.84^{b} (2.88)	1.91^{cd} (3.14)	1.85^{b} (2.92)	1.78^{b} (2.66)	1.66^{b} (2.25)	1.40^{b} (1.46)	1.61^{b} (2.09)	1.73^{c} (2.49)
5	Emamectin benzoate 5% SG	0.0019	2.03^{a} (3.62)	1.71^{ab} (2.42)	1.47^{a} (1.66)	1.58^{ab} (1.99)	1.59^{a} (2.02)	1.41^{a} (1.48)	1.31^{a} (1.21)	1.08^{a} (0.66)	1.26^{a} (1.08)	1.43^{b} (1.54)
6	Emamectin benzoate 5% SG	0.0024	1.99^{a} (3.46)	1.65^{ab} (2.22)	1.41^{a} (1.48)	1.55^{a} (1.90)	1.54^{a} (1.87)	1.37^{a} (1.37)	1.24^{a} (1.03)	1.04^{a} (0.58)	1.22^{a} (0.98)	1.38^{ab} (1.40)
7	Quinalphos 25% EC	0.05	2.01^{a} (3.54)	1.78^{ab} (2.67)	2.00^{bc} (3.50)	2.06^{cd} (3.74)	1.95^{bc} (3.30)	1.93^{bc} (3.22)	1.82^{b} (2.81)	1.60^{b} (2.06)	1.78^{c} (2.66)	1.87^{d} (2.99)
8	Control	--	2.09^{a} (3.87)	2.02^{b} (3.58)	2.16^{c} (4.16)	2.18^{d} (4.25)	2.12^{c} (3.99)	2.20^{c} (4.34)	2.22^{c} (4.42)	2.25^{c} (4.56)	2.22^{d} (4.42)	2.17^{e} (4.20)
	S. Em. ±	Treatment (T)	0.11	0.11	0.07	0.08	0.05	0.09	0.08	0.07	0.04	0.03
		Period (P)	--	--	--	--	0.03	--	--	--	0.03	0.02
		T X P	--	--	--	--	0.09	--	--	--	0.08	0.06
	C.V.%		9.45	10.90	7.25	8.42	9.03	9.79	9.24	9.67	9.66	9.30

Notes:
1. Figures in parenthesis are retransformed values; those outside are $\sqrt{x+0.5}$ transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance
3. Significant parameters and their interaction: S, P, S X P, T, S X T
4. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 3: Bioefficacy of insecticides on leaf eating caterpillar infesting drumstick (Pooled over years)

Sr. No.	Insecticides	Conc. (%)	No. of larva (e)/ 5 shoots		
			2018	2019	Pooled
1	Chlorantraniliprole 18.5% SC	0.0045	1.74^{c} (2.53)	1.70^{c} (2.39)	1.71^{b} (2.42)
2	Chlorantraniliprole 18.5% SC	0.006	1.48^{b} (1.69)	1.42^{b} (1.51)	1.44^{a} (1.57)
3	Chlorantraniliprole 18.5% SC	0.0075	1.38^{a} (1.40)	1.32^{a} (1.24)	1.35^{a} (1.32)
4	Emamectin benzoate 5% SG	0.0014	1.78^{c} (2.67)	1.73^{c} (2.49)	1.75^{b} (2.56)
5	Emamectin benzoate 5% SG	0.0019	1.49^{b} (1.72)	1.43^{b} (1.54)	1.45^{a} (1.60)
6	Emamectin benzoate 5% SG	0.0024	1.45^{ab} (1.60)	1.38^{ab} (1.40)	1.41^{a} (1.49)
7	Quinalphos 25% EC	0.05	1.91^{d} (3.15)	1.87^{d} (2.99)	1.88^{b} (3.03)
8	Control	--	2.17^{e} (4.21)	2.17^{e} (4.20)	2.16^{c} (4.17)
	S. Em. ±	Treatment (T)	0.03	0.03	0.06
		Period (P)	0.02	0.02	0.04
		T X P	0.06	0.06	0.11
	C.V.%		8.96	9.30	9.13
Notes :	1. Figures in parenthesis are retransformed values; those outside are transformed values 2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at 5% level of significance 3. Significant parameters and its interaction: S, P, S X P, T, S X T, P X T 4. The concentration and requirement of formulation in 10 litres of water was calculated based on 500 litres of water/ha				

Table 4: Effect of insecticides on damage caused by leaf eating caterpillar in drumstick during 2018

Sr. No.	Insecticides	Conc. (%)	Shoot damage (%) days after spray									Pooled over sprays
			First					Second				
			Before spray	5	10	15	Pooled	5	10	15	Pooled	
1	Chlorantraniliprole 18.5% SC	0.0045	71.92^{a} (90.37)	61.20^{ab} (76.79)	62.27^{b} (78.35)	63.90^{bcd} (80.65)	62.45^{b} (78.61)	60.29^{bcd} (75.44)	51.75^{bcd} (61.67)	44.02^{bc} (44.81)	52.02^{b} (62.13)	57.24^{b} (70.72)
2	Chlorantraniliprole 18.5% SC	0.006	68.63^{a} (86.72)	55.96^{a} (68.67)	50.77^{a} (60.00)	52.86^{ab} (63.55)	53.19^{a} (64.10)	49.87^{ab} (58.46)	42.07^{ab} (44.90)	35.24^{ab} (33.29)	42.39^{a} (45.45)	47.79^{a} (54.86)
3	Chlorantraniliprole 18.5% SC	0.0075	77.04^{a} (94.97)	54.76^{a} (66.71)	49.81^{a} (58.36)	51.73^{a} (61.64)	52.10^{a} (62.27)	48.82^{a} (56.65)	41.15^{a} (43.30)	33.06^{a} (29.76)	41.01^{a} (43.06)	46.56^{a} (52.72)
4	Emamectin benzoate 5% SG	0.0014	79.32^{a} (96.57)	62.45^{abc} (78.61)	63.83^{b} (80.55)	64.97^{cd} (82.10)	63.75^{b} (80.44)	61.31^{cd} (76.95)	52.86^{cd} (63.55)	45.01^{bc} (50.02)	53.06^{b} (63.88)	58.41^{bc} (72.56)
5	Emamectin benzoate 5% SG	0.0019	71.53^{a} (89.96)	58.34^{ab} (72.45)	52.84^{a} (63.51)	53.79^{abc} (65.10)	54.99^{a} (67.08)	50.80^{abc} (60.05)	43.03^{abc} (46.56)	35.10^{ab} (33.06)	42.98^{a} (46.48)	48.98^{a} (56.92)
6	Emamectin benzoate 5% SG	0.0024	76.03^{a} (94.17)	56.98^{a} (70.30)	51.79^{a} (61.74)	56.01^{abc} (68.75)	54.92^{a} (66.97)	52.89^{abc} (63.60)	44.98^{abc} (49.97)	37.21^{ab} (36.57)	45.03^{a} (50.05)	49.98^{a} (58.65)
7	Quinalphos 25% EC	0.05	71.53^{a} (89.96)	68.83^{bc} (86.96)	66.12^{bc} (83.61)	69.52^{de} (87.76)	68.16^{b} (86.16)	65.16^{de} (82.35)	56.82^{d} (70.05)	48.82^{c} (56.65)	56.93^{b} (70.23)	62.54^{c} (78.74)
8	Control	--	71.92^{a} (90.37)	73.76^{c} (92.18)	75.21^{c} (93.48)	77.05^{e} (94.98)	75.34^{c} (93.59)	75.21^{e} (93.48)	81.16^{e} (97.64)	85.28^{d} (99.32)	80.55^{c} (97.30)	77.95^{d} (95.64)
	S. Em. ±	Treatment (T)	3.40	3.46	2.70	3.51	1.87	3.32	3.01	2.99	1.79	1.29
		Period (P)	--	--	--	--	1.15	--	--	--	1.10	0.79
		T X P	--	--	--	--	3.25	--	--	--	3.11	2.25
	C.V.%		8.01	9.76	7.93	9.94	9.28	9.90	10.09	8.96	10.41	9.81
Notes:	1. Figures in parenthesis are retransformed values; those outside are arc sine transformed values 2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance 3. Significant parameters and their interaction: S, P, S X P, T, S X T 4. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha											

Table 5: Effect of insecticides on damage caused by leaf eating caterpillar in drumstick during 2019

Sr. No.	Insecticides	Conc. (%)	Shoot damage (%) days after spray									Pooled over sprays
			First					Second				
			Before spray	5	10	15	Pooled	5	10	15	Pooled	
1	Chlorantraniliprole 18.5% SC	0.0045	65.92^{a} (83.35)	57.89^{abc} (71.75)	58.91^{b} (73.33)	60.29^{bcd} (75.44)	59.03^{b} (73.52)	55.75^{abc} (68.33)	48.86^{bcd} (56.72)	41.15^{bc} (43.30)	48.58^{b} (56.23)	53.81^{b} (65.14)
2	Chlorantraniliprole 18.5% SC	0.006	65.92^{a} (83.35)	52.86^{a} (63.55)	47.86^{a} (54.98)	49.87^{ab} (58.46)	50.19^{a} (59.01)	46.93^{a} (53.37)	39.10^{ab} (39.78)	32.13^{a} (28.29)	39.39^{a} (40.27)	44.79^{a} (49.63)
3	Chlorantraniliprole 18.5% SC	0.0075	70.08^{a} (88.39)	51.76^{a} (61.69)	46.90^{a} (53.31)	48.82^{a} (56.65)	49.16^{a} (57.24)	45.94^{a} (51.64)	38.23^{a} (38.29)	29.91^{a} (24.86)	38.03^{a} (37.95)	43.59^{a} (47.54)
4	Emamectin benzoate 5% SG	0.0014	70.08^{a} (88.39)	59.03^{abc} (73.52)	60.24^{b} (75.36)	61.31^{cd} (76.95)	60.19^{b} (75.29)	57.96^{bc} (71.86)	49.78^{cd} (58.30)	42.10^{c} (44.95)	49.95^{b} (58.60)	55.07^{b} (67.22)
5	Emamectin benzoate 5% SG	0.0019	65.92^{a} (83.35)	55.05^{ab} (67.18)	49.84^{a} (58.41)	50.80^{abc} (60.05)	51.9^{a} (61.93)	49.88^{ab} (58.48)	42.10^{abc} (44.95)	34.01^{ab} (31.29)	42.00^{a} (44.77)	46.95^{a} (53.40)
6	Emamectin benzoate 5% SG	0.0024	67.37^{a} (85.19)	53.84^{ab} (65.19)	48.85^{a} (56.70)	49.88^{ab} (58.48)	50.86^{a} (60.16)	47.87^{a} (55.00)	40.16^{abc} (41.59)	32.13^{a} (28.29)	40.05^{a} (41.40)	45.45^{a} (50.79)
7	Quinalphos 25% EC	0.05	65.92^{a} (83.35)	64.78^{bc} (64.78)	62.38^{b} (78.51)	65.16^{de} (82.35)	64.11^{b} (80.93)	61.43^{c} (77.13)	53.74^{d} (65.02)	45.94^{c} (51.64)	53.70^{b} (64.95)	58.91^{c} (73.33)
8	Control	--	70.08^{a} (88.39)	68.83^{c} (86.96)	73.37^{c} (91.81)	73.37^{e} (91.81)	71.86^{c} (90.31)	75.21^{d} (93.48)	79.33^{e} (96.57)	85.28^{d} (99.32)	79.94^{c} (96.65)	75.9^{d} (94.07)
	S. Em. ±	Treatment (T)	1.50	3.24	2.57	3.30	1.76	2.92	2.98	2.29	1.58	1.18
		Period (P)	--	--	--	--	1.08	--	--	--	0.97	0.72
		T X P	--	--	--	--	3.05	--	--	--	2.75	2.05
	C.V.%		3.85	9.71	7.96	9.96	9.26	9.17	10.57	9.28	9.73	9.49

Notes :
1. Figures in parenthesis are retransformed values; those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance
3. Significant parameters and its interaction: S, P, S X P, T, S X T, P X T
4. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 6: Effect of insecticides on damage caused by leaf eating caterpillar in drumstick (Pooled over years)

Sr. No.	Insecticides	Conc. (%)	Shoot damage (%)		
			2018	2019	Pooled
1	Chlorantraniliprole 18.5% SC	0.0045	57.24^{b} (70.72)	53.81^{b} (65.14)	55.52^{c} (67.95)
2	Chlorantraniliprole 18.5% SC	0.006	47.79^{a} (54.86)	44.79^{a} (49.63)	46.29^{ab} (52.25)
3	Chlorantraniliprole 18.5% SC	0.0075	46.56^{a} (52.72)	43.59^{a} (47.54)	45.07^{a} (50.12)
4	Emamectin benzoate 5% SG	0.0014	58.41^{bc} (72.56)	55.07^{b} (67.22)	56.74^{c} (69.92)
5	Emamectin benzoate 5% SG	0.0019	48.98^{a} (56.92)	46.95^{a} (53.40)	47.96^{b} (55.16)
6	Emamectin benzoate 5% SG	0.0024	49.98^{a} (58.65)	45.45^{a} (50.79)	47.71^{b} (54.72)
7	Quinalphos 25% EC	0.05	62.54^{c} (78.74)	58.91^{c} (73.33)	60.72^{d} (76.08)
8	Control	--	77.95^{d} (95.64)	75.9^{d} (94.07)	76.92^{e} (94.88)
	S. Em. ±	Treatment (T)	1.29	1.18	0.87
		Period (P)	0.79	0.72	0.53
		T X P	2.25	2.05	1.47
	C.V.%		9.81	9.49	9.67

Notes:
1. Figures in parenthesis are retransformed values; those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance
3. Significant parameters and their interaction: S, P, S X P, T, S X T, P X T, S X P X T
4. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 7: Effect of insecticides on spiders in drumstick during 2018

Sr. No.	Insecticides	Conc. (%)	No. of spider(s)/ 5 shoots days after spray									Pooled over sprays
			First					Second				
			Before spray	5	10	15	Pooled	5	10	15	Pooled	
1	Chlorantraniliprole 18.5% SC	0.0045	0.79^{a} (0.12)	0.79^{a} (0.12)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.76^{a} (0.08)	0.75^{a} (0.06)	0.79^{a} (0.12)	0.75^{a} (0.06)	0.76^{a} (0.08)	0.76^{a} (0.08)
2	Chlorantraniliprole 18.5% SC	0.006	0.78^{a} (0.11)	0.75^{a} (0.06)	0.79^{a} (0.12)	0.79^{a} (0.12)	0.77^{a} (0.09)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.76^{a} (0.08)
3	Chlorantraniliprole 18.5% SC	0.0075	0.75^{a} (0.06)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.70^{a} (0.01)	0.73^{a} (0.03)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.70^{a} (0.01)	0.73^{a} (0.03)	0.73^{a} (0.03)
4	Emamectin benzoate 5% SG	0.0014	0.75^{a} (0.06)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.75^{a} (0.06)	0.83^{a} (0.19)	0.75^{a} (0.06)	0.83^{a} (0.19)	0.80^{a} (0.14)	0.77^{a} (0.09)
5	Emamectin benzoate 5% SG	0.0019	0.70^{a} (0.01)	0.70^{a} (0.01)	0.83^{a} (0.19)	0.75^{a} (0.06)	0.76^{a} (0.08)	0.75^{a} (0.06)	0.78^{a} (0.11)	0.75^{a} (0.06)	0.76^{a} (0.08)	0.76^{a} (0.08)
6	Emamectin benzoate 5% SG	0.0024	0.75^{a} (0.06)	0.78^{a} (0.11)	0.82^{a} (0.17)	0.75^{a} (0.06)	0.78^{a} (0.11)	0.75^{a} (0.06)	0.70^{a} (0.01)	0.75^{a} (0.06)	0.73^{a} (0.03)	0.76^{a} (0.08)
7	Quinalphos 25% EC	0.05	0.75^{a}	0.78^{a}	0.75^{a}	0.79^{a}	0.77^{a}	0.75^{a}	0.75^{a}	0.75^{a}	0.75^{a}	0.76^{a}

			(0.06)	(0.11)	(0.06)	(0.12)	(0.09)	(0.06)	(0.06)	(0.06)	(0.06)	(0.08)
8	Control	--	0.83[a] (0.19)	0.75[a] (0.06)	0.87[a] (0.26)	0.83[a] (0.19)	0.81[a] (0.16)	0.79[a] (0.12)	0.87[a] (0.26)	0.83[a] (0.19)	0.83[a] (0.19)	0.82[a] (0.17)
	S. Em. ±	Treatment (T)	0.05	0.05	0.06	0.04	0.03	0.05	0.05	0.05	0.03	0.02
		Period (P)	--	--	--	--	0.02	--	--	--	0.02	0.01
		T X P	--	--	--	--	0.05	--	--	--	0.05	0.03
	C.V.%		11.51	12.03	13.10	10.13	11.85	10.70	10.42	11.05	10.73	11.30

Notes:
1. Figures in parenthesis are retransformed values; those outside are $\sqrt{x+0.5}$ transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance
3. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 8: Effect of insecticides on spiders in drumstick during 2019

Sr. No.	Insecticides	Conc. (%)	No. of spider(s)/ 5 shoots days after spray									Pooled over sprays
			First					Second				
			Before spray	5	10	15	Pooled	5	10	15	Pooled	
1	Chlorantraniliprole 18.5% SC	0.0045	0.95[a] (0.40)	0.91[a] (0.33)	0.83[a] (0.19)	0.87[a] (0.26)	0.87[a] (0.26)	0.84[a] (0.21)	0.91[a] (0.33)	0.84[a] (0.21)	0.86[a] (0.24)	0.87[a] (0.26)
2	Chlorantraniliprole 18.5% SC	0.006	0.91[a] (0.33)	0.87[a] (0.26)	0.91[a] (0.33)	0.91[a] (0.33)	0.90[a] (0.31)	0.84[a] (0.21)	0.83[a] (0.19)	0.79[a] (0.12)	0.82[a] (0.17)	0.86[a] (0.24)
3	Chlorantraniliprole 18.5% SC	0.0075	0.91[a] (0.33)	0.83[a] (0.19)	0.87[a] (0.26)	0.71[a] (0.00)	0.80[a] (0.14)	0.87[a] (0.26)	0.79[a] (0.12)	0.79[a] (0.12)	0.82[a] (0.17)	0.81[a] (0.16)
4	Emamectin benzoate 5% SG	0.0014	0.83[a] (0.19)	0.83[a] (0.19)	0.87[a] (0.26)	0.87[a] (0.26)	0.86[a] (0.24)	0.83[a] (0.19)	0.84[a] (0.21)	0.79[a] (0.12)	0.82[a] (0.17)	0.84[a] (0.21)
5	Emamectin benzoate 5% SG	0.0019	0.87[a] (0.26)	0.79[a] (0.12)	0.91[a] (0.33)	0.87[a] (0.26)	0.86[a] (0.24)	0.87[a] (0.26)	0.87[a] (0.26)	0.75[a] (0.06)	0.83[a] (0.19)	0.84[a] (0.21)
6	Emamectin benzoate 5% SG	0.0024	0.91[a] (0.33)	0.91[a] (0.33)	0.83[a] (0.19)	0.91[a] (0.33)	0.88[a] (0.27)	0.79[a] (0.12)	0.84[a] (0.21)	0.83[a] (0.19)	0.82[a] (0.17)	0.85[a] (0.22)
7	Quinalphos 25% EC	0.05	0.83[a] (0.19)	0.89[a] (0.29)	0.84[a] (0.21)	0.83[a] (0.19)	0.84[a] (0.21)	0.79[a] (0.12)	0.83[a] (0.19)	0.79[a] (0.12)	0.80[a] (0.14)	0.83[a] (0.19)
8	Control	--	0.95[a] (0.40)	0.87[a] (0.26)	0.87[a] (0.26)	0.91[a] (0.33)	0.87[a] (0.26)	0.91[a] (0.33)	0.87[a] (0.26)	0.91[a] (0.33)	0.90[a] (0.31)	0.89[a] (0.29)
	S. Em. ±	Treatment (T)	0.04	0.05	0.05	0.05	0.03	0.05	0.04	0.04	0.03	0.02
		Period (P)	--	--	--	--	0.02	--	--	--	0.02	0.01
		T X P	--	--	--	--	0.05	--	--	--	0.04	0.03
	C.V.%		8.46	10.93	10.43	9.62	10.34	9.71	9.07	9.41	9.40	9.90

Notes:
1. Figures in parenthesis are retransformed values; those outside are $\sqrt{x+0.5}$ transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at a 5% level of significance
3. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 9: Effect of insecticides on spiders in drumstick (Pooled over years)

Sr. No.	Insecticides	Conc. (%)	No. of spider(s)/ 5 shoots		
			2018	2019	Pooled
1	Chlorantraniliprole 18.5% SC	0.0045	0.76[a] (0.08)	0.87[a] (0.26)	0.81 [a] (0.16)
2	Chlorantraniliprole 18.5% SC	0.006	0.76[a] (0.08)	0.86[a] (0.24)	0.81 [a] (0.16)
3	Chlorantraniliprole 18.5% SC	0.0075	0.73[a] (0.03)	0.81[a] (0.16)	0.77 [a] (0.09)
4	Emamectin benzoate 5% SG	0.0014	0.77[a] (0.09)	0.84[a] (0.21)	0.80 [a] (0.14)
5	Emamectin benzoate 5% SG	0.0019	0.76[a] (0.08)	0.84[a] (0.21)	0.80 [a] (0.14)
6	Emamectin benzoate 5% SG	0.0024	0.76[a](0.08)	0.85[a] (0.22)	0.81 [a] (0.16)
7	Quinalphos 25% EC	0.05	0.76[a] (0.08)	0.83[a] (0.19)	0.79 [a] (0.12)
8	Control	--	0.82[a] (0.17)	0.89[a] (0.29)	0.86 [a] (0.24)
	S. Em. ±	Treatment (T)	0.02	0.02	0.01
		Period (P)	0.01	0.01	0.01
		T X P	0.03	0.03	0.02
	C.V.%		11.30	9.90	10.57

Notes :
1. Figures in parenthesis are retransformed values; those outside are $\sqrt{x+0.5}$ transformed values
2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at 5% level of significance
3. The concentration and requirement of formulation in 10 litres of water were calculated based on 500 litres of water/ha

Table 10: Economics of insecticides evaluated against leaf eating caterpillar infesting drumstick

Tr. No.	Treatments	Conc. (%)	Required quantity of insecticides for two applications (g/ha)	Cost of insecticides per kg or lit.	Total cost of insecticides (Rs/ha)	Labour charges (Rs/ha)	Total cost of plant protection (Rs/ha)
1	Chlorantraniliprole 18.5% SC	0.0045	225	16617	3739	2684	6423
2	Chlorantraniliprole 18.5% SC	0.006	300	16617	4985	2684	7669
3	Chlorantraniliprole 18.5% SC	0.0075	375	16617	6231	2684	8915
4	Emamectin benzoate 5% SG	0.0014	285	6100	1739	2684	4422
5	Emamectin benzoate 5% SG	0.0019	380	6100	2318	2684	5002
6	Emamectin benzoate 5% SG	0.0024	475	6100	2898	2684	5581
7	Quinalphos 25% EC	0.05	2000	544	1088	2684	3772
8	Control	--	--	--	--	--	--

Note: Labour charges @ Rs. 335.4/- per day x 4 labours = 1342 Rs /ha

Conclusion

Treatments of chlorantraniliprole 18.5% SC 0.0075%, chlorantraniliprole 18.5% SC 0.006%, emamectin benzoate 5% SG 0.0024% and emamectin benzoate 5% SG 0.0019% were found effective and economical in managing leaf eating caterpillar in drumstick.

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