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Biology and management of the ginger shoot borer, *Conogethes punctiferalis* Guenee (Lepidoptera: Crambidae)

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ABSTRACT: A study on the biology of the ginger shoot borer, *Conogethes punctiferalis* Guenee, conducted during 2024 at the College of Agriculture, Shivamogga, Karnataka, showed that the incubation, larval, pre-pupal and pupal periods were 3.72 ± 0.25, 21.25 ± 1.76, 2.90 ± 0.20 and 7.75 ± 0.29 days, respectively. On ginger, the mean pre-oviposition, oviposition and post-oviposition periods lasted 3.00 ± 0.50, 2.40 ± 0.22 and 2.60 ± 0.22 days, respectively. A female laid an average of 45.00 ± 8.12 eggs. Adult longevity of male and female moths was 7.20 ± 0.27 and 7.90 ± 0.65 days, respectively. The total life cycle on ginger was 42.50 ± 3.53 days for males and 43.50 ± 4.24 days for females. In the bio-efficacy trial against the ginger shoot borer, spinetoram 11.7 % SC @100 ml/acre was the most effective insecticide, reducing damage by 60.61 per cent over the untreated control and recording the lowest mean damage across both sprays. Lambda-cyhalothrin 5 % EC @ 80 ml/acre offered better sustained control, whereas cartap hydrochloride 4 % G @ 10,000 g/acre, chlorantraniliprole 0.4 % G @ 4,000 g/acre, imidacloprid 70 % WG @ 400 g/acre and azadirachtin 1 % EC @ 400 ml/acre were moderately effective in managing the ginger shoot borer.

Keywords: *Conogethes punctiferalis*, ginger, life cycle, management.

INTRODUCTION

Ginger (*Zingiber officinale* Rosc., F: Zingiberaceae), is an important cash crop cultivated mainly for its underground rhizome, which is widely used as a spice, condiment and in traditional medicine. It is rich in secondary metabolites such as oleoresin and grows well under warm, humid conditions in well-drained soils, performing best at 19- 28 ^{0}C with 70 to 90 per cent relative humidity (Jayashree *et al*., 2015). India is one of the leading ginger producers globally, with an average yield of 10.72 tonnes per ha from an area of 1,75,764 ha and a production of about 1,780,000 MT. In Karnataka, during 2023–24, ginger was cultivated in 21.34 thousand ha, producing 232.84 thousand MT with a productivity of 10.91 MT per ha (Indiastat, 2023-24). Ginger shoot borer *Conogethes sahyadriensis* Guenee (Lepidoptera: Crambidae), is a major pest that causes considerable damage in ginger. Yield losses of up to 25 per cent have been reported (Devasahayam, 2000). Under severe infestation, losses in ginger rhizome alone may reach 26.78 per cent (Kasareddy, 2017). In ginger and turmeric, shoot borer damage can even cause yield losses up to 50 per cent (Senthil *et al*., 2015). The female moth lays spherical, pale-yellow eggs on young, unopened leaves. After hatching, neonate larvae scrape chlorophyll from the leaf surface. With further growth, larvae bore into shoots and feed internally, producing the typical "dead heart" symptom. In most cases, larvae complete development before reaching the rhizome and then leave the stem to pupate; however, they may occasionally reach the rhizome and cause injury (Chong *et al*., 1991).

Insecticides play an important role in managing *C. punctiferalis*, and carbofuran, lambda-cyhalothrin and chlorpyrifos have shown high efficacy, whereas neem-based formulations are generally less effective. However, their effectiveness often declines after 15 days, necessitating repeated applications or integration with other approaches (Chethan *et al*., 2017). Reduced-risk pesticides, which are relatively safer to humans, non-target organisms and the environment, provide a more sustainable option (Fishel, 2019). Despite the economic importance of ginger, information on the biology and management of the shoot borer is limited. Hence, the present study was undertaken to investigate the biology of *C. punctiferalis* and to evaluate newer insecticidal molecules.

MATERIALS AND METHODS

Biology of Shoot borer, *Conogethes punctiferalis*

The biology of the shoot borer was studied under laboratory conditions (25 ± 1°C and 70–80% RH) in the Department of Entomology, College of Agriculture, Navile, Shivamogga during 2024-25.

Rearing of *C. punctiferalis*

Field-collected larvae and pupae were used to initiate the culture of *C. punctiferalis* on ginger. Larvae were reared on ginger pseudostems maintained in round plastic boxes in the laboratory until pupation (Fig. 1). Four days after pupation, pupae were sexed into males and females by examining the distance between the genital and anal slits under a microscope. Newly emerged adult males and females were used for subsequent studies. Five pairs of adults were released individually in cages for mating and oviposition. Before confinement, fresh tender ginger shoots were excised and their basal ends were kept immersed in a conical flask containing water to retain turgidity. Oviposition cages were maintained for studying biology on ginger. A cotton wad dipped in ten per cent sugar solution was kept in a Petri plate to provide food for the moths. Shoots were examined daily to locate eggs laid by *C. punctiferalis* and were replaced each day to encourage continuous egg laying. Plant parts bearing freshly laid eggs were transferred to petri dishes for incubation. After hatching, larvae were provided with fresh ginger pseudostems and rearing was continued until adult emergence.

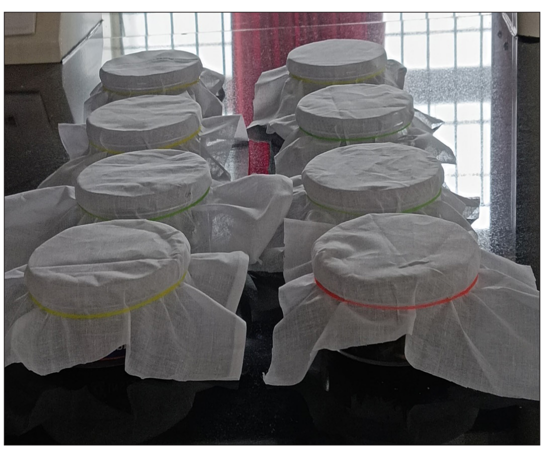

Fig 1. Experimental setup to study the biology of *C. punctiferalis* on ginger

The developmental biology of *C. punctiferalis* was studied under laboratory conditions (25±1 ^{0}C and 70-80 per cent RH) using fresh ginger pseudostems. Uniform-aged neonates were transferred onto cut pseudostem pieces using a soft camel hair brush (size 00). Five replications were maintained, with ten larvae per replication. Observations were made at 24-hour intervals to record larval duration, instar size, number of larval instars and instar weight.

Stages of *C. punctiferalis*

Eggs were observed under a stereo microscope (Zeiss Stemi 508, Carl Zeiss Microscopy) and gently removed from the substrate with a soft camel hair brush (size 00). The incubation period (egg laying to hatching) was recorded at 24-hour intervals, and eggs laid per female were counted daily until adult death. Newly hatched larvae were transferred to tender ginger pseudostems in petri plates, and larval development was monitored until pupation. Uniform-aged larvae were released individually on ginger shoots and shoots were replaced as required. Larval length (cephalic to caudal end), breadth (thoracic region) and weight were recorded for each instar (n=10) using a stereo-zoom binocular microscope (LAB MICRO). The pre-pupal period was recorded from cessation of feeding to pupation, and the length and breadth of ten pre-pupae were measured. Male and female pupae were differentiated based on the distance between anal and genital slits. Pupal period was recorded from pupation to adult emergence, and pupal length and breadth were measured for both sexes.

Reproductive parameters of *C. punctiferalis*

Freshly emerged male and female moths were paired and released onto ginger pseudostems bearing tender leaves inside oviposition cages. Five replications were maintained to study pre-oviposition, oviposition, post-oviposition and fecundity. The interval between female emergence and first egg deposition was considered the pre-oviposition period. The period from onset of egg deposition to cessation of egg laying was taken as the oviposition period, while the period from cessation of egg laying to female death was considered the post-oviposition period. Total fecundity was recorded as the total number of eggs laid per female during the oviposition period. Adult longevity was determined using freshly emerged moths (five males and five females), which were released separately into rearing cages, provided with ten per cent sugar solution in a cotton wad, and observed daily. The food (10 % sugar solution) was replaced once every two days. Longevity of male and female moths was recorded. The duration from freshly laid egg to death of the adult was recorded and considered as the total life cycle of *C. punctiferalis*.

Management of Shoot borer, *C. punctiferalis*

A field experiment was conducted during Kharif 2025 at the University of Agricultural and Horticultural Sciences, Iruvakki, Karnataka, in a Randomized Block Design with plot size of 2 × 3 m. The Himachal local ginger cultivar was planted at a spacing of 30 × 30 cm (rhizome to rhizome × row to row) and the crop was maintained following the recommended package of practices for the region (Anonymous, 2013), except for insecticide sprays against insect pests. Six insecticides with different modes of action spinetoram 11.7 % SC @100 ml/acre, lambda-cyhalothrin 5 % EC @ 80 ml/acre, cartap hydrochloride 4 % G @ 10,000 g/acre, chlorantraniliprole 0.4 % G @ 4,000 g/acre, imidacloprid 70 % WG @ 400 g/acre and azadirachtin 1 % EC @ 400 ml/acre were evaluated along with an untreated control (Table 1). Spraying was initiated when the first symptoms of pest attack were noticed. Treatments were imposed using a knapsack high-volume sprayer during morning hours (7-8 AM). Observations on shoot borer damage were recorded from five randomly selected clumps per treatment. Data were recorded one day before treatment and at 3, 7 and 15 days after treatment (DAT) following each spray. The experiment was replicated three times. The data were subjected to statistical analysis (ANOVA) to determine treatment significance, and means were separated using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) at P=0.05. Percent shoot damage by *C. punctiferalis* was calculated using the formula given below.

$$\text{Infestation (\%)} = \frac{\text{Number of shoots infested per plot}}{\text{Total number of shoots per plot}} \times 100$$

Table 1. List of insecticides used for management against *Conogethes punctiferalis* in ginger

SI. No	Chemical name	Formulation	Dosage	Trade name
T_1	Lambda-cyhalothrin	5% EC	80 ml/acre	Agent plus®
T_2	Cartap hydrochloride	4% G	10,000 g/acre	Caldan ® 4G
T_3	Spinetoram	11.7% SC	100 ml/acre	Summit®
T_4	Imidacloprid	70% WG	400 g/acre	Ad-fyre®
T_5	Chlorantraniliprole	0.4% G	4,000 g/acre	Ferterra ®
T_6	Azadirachtin	1% EC	400 ml/acre	Agro neem
T_7	Untreated check	-	-	-

Eggs of *C. punctiferalis*

First instar

Second instar

Third instar

Fourth instar

Fifth instar

Fig 2. Eggs and different larval instars of *C. punctiferalis*

The fresh bore holes on pseudostems were noted. Percent damage was estimated and percent reduction over control was worked out using the formula given below.

$$\text{Per cent reduction over control (\%)} = \frac{\text{Borer damage in control} - \text{borer damage in treatment}}{\text{Borer damage in control}} \times 100$$

RESULTS AND DISCUSSION

Biology of shoot borer, *C. punctiferalis*

The *C. punctiferalis* laid eggs either singly or in small clusters, mainly near the leaf apex or in the leaf axils of ginger. Freshly laid eggs were milky white and nearly round (Fig. 2). Close to hatching, eggs turned dark brown and the developing larval head became visible. The incubation period on ginger ranged from 3.50 to 4.00 days with a mean of 3.72 ± 0.25 days (Table 2). This agrees with Kasareddy (2017), who reported 3.00-4.50 days, but was longer than the 2.35 days reported by Satyanarayana and Arunakumara (2017), likely due to differences in temperature and humidity. Mean egg length was 0.58 ± 0.05 mm (range: 0.48–0.64 mm) and mean width was 0.44 ± 0.02 mm (range: 0.40–0.48 mm) (Table 3), which closely matches Kasareddy (2017) and Satyanarayana and Arunakumara (2017).

Eggs hatched mostly during night hours (7 to 8 PM). The larva underwent four moults, indicating five larval instars (Fig. 2). Duration and size of each larval instar are presented in Table 2 and 3. Newly hatched larvae were initially sluggish but became active a few hours after emergence. They were tiny, transparent pink, with short scattered hairs arising from dark tubercles, a proportionally large dark head, a smooth body with a brown prothoracic shield, and faint black spots. First instar larval length ranged from 1.50-1.68 mm (mean

Table 2. Developmental biology of *Conogethes punctiferalis* on ginger under laboratory conditions

Sl. No	Stages	Range (days)	Mean ± SD (days)
1	Egg stage	3.50-4.00	3.72 ± 0.25
2	Larval instars		
	1st instar	3.00-3.50	3.20 ± 0.24
	2nd instar	3.50-4.00	3.70 ± 0.24
	3rd instar	3.50-4.00	3.80 ± 0.23
	4th instar	4.50-5.00	4.82 ± 0.24
	5th instar	5.50-6.00	5.60 ± 0.37
3	Total larval period	20.00-22.50	21.25 ± 1.76
4	Pre-pupal period	2.50-3.00	2.90 ± 0.20
5	Pupal period	7.00-8.00	7.75 ± 0.29
6	Pre-oviposition##	2.50-3.50	3.0 ± 0.50
7	Oviposition##	2.0-2.50	2.40 ± 0.22
8	Post-oviposition##	2.50-3.00	2.60 ± 0.22
9	Fecundity (no.) ##	28.00-35.00	31.00 ± 2.91
10	Adult		
	Male##	7.00-7.50	7.20 ± 0.27
	Female##	7.50-9.00	7.90 ± 0.65
11	Total developmental period		
	Male##	40.00-45.00	42.50 ± 3.53
	Female##	40.50-46.50	43.50 ± 4.24

Note: n = 50, ## Mean of 5 observations

1.60 ± 0.05 mm) and width ranged from 0.20-0.25 mm (mean 0.22 ± 0.01 mm) (Table 3). Duration of the first instar ranged from 3.00-3.50 days (mean 3.20 ± 0.24 days) (Table 2). Larval weight ranged from 8.50-11.50 mg with a mean of 9.07 ± 0.97 mg (Table 4). Second instar larvae were larger and broader than the head, pale yellow and semi-transparent, with short hairs on dark tubercles. The head was black, spiracles were brown, body patches were faint, and a distinct brown prothoraxic shield was visible. Larval length ranged from 3.10-3.70 mm (mean 3.37 ± 0.17 mm) and width ranged from 0.35-0.40 mm (mean 0.36 ± 0.01 mm) (Table 3). The second instar duration ranged from 3.50-4.00 days (mean 3.70 ± 0.24 days) (Table 2). Larval weight ranged from 15.45-26.35 mg with a mean of 17.78 ± 3.20 mg (Table 4).

The last three instars were similar in colour and morphology to earlier stages, with size being the main distinguishing feature. Larvae had a pale brown body with a dark brown head capsule, prothoracic shield and sclerotized plates, and deep-pigmented spots were clearly visible. When disturbed, larvae descended using a thin silken thread. Third instar length ranged from 5.70-6.20 mm (mean 5.94 ± 0.18 mm) and width ranged from 0.80-0.92 mm (mean 0.86 ± 0.03 mm) (Table 3). Third instar duration ranged from 3.50-4.00 days (mean 3.80 ± 0.23 days) (Table 2). Fourth instar length ranged from 12.20-13.10 mm (mean 12.80 ± 0.27 mm) and width ranged from 1.55-1.68 mm (mean 1.60 ± 0.04 mm) (Table 3), with duration of 4.50-5.00 days (mean 4.82 ± 0.24 days) (Table 2). Fifth instar length ranged from 15.50-16.50 mm (mean 16.01 ± 0.29 mm) and width ranged from 2.32–2.60 mm (mean 2.48 ± 0.08 mm) (Table 3), with duration of 5.50-6.00 days (mean 5.60 ± 0.37 days) (Table 2). Mean larval weights in the third, fourth and fifth instars were 44.8 ± 2.96, 77.54 ± 3.17 and 104.07 ± 2.33 mg, respectively (Table 4). Total larval duration in the laboratory ranged from 20.00–22.50 days with a mean of 21.25 ± 1.76 days (Table 2). Stanley *et al*. (2009) reported a 24-day larval period for *C. punctiferalis* on ginger in Karnataka, supporting the present findings. Satyanarayana and Arunakumara (2017) observed a shorter duration (11.24–12.51 days), while Kasareddy (2017) recorded a longer larval period (27.50 ± 2.30 days), likely reflecting seasonal and location-specific variation.

Fig 3. Pre pupa of *C. punctiferalis* Pupa of *C. punctiferalis* Female pupa Male pupa

Table 3. Morphometrics of different stages of ginger shoot borer, *Conogethes punctiferalis* reared on ginger

Insect life stages	Length (mm)		Width (mm)	
	Range	Mean ± SD [n]	Range	Mean ± SD [n]
Egg stage	0.48-0.64	0.58 ± 0.05	0.40-0.48	0.44 ± 0.02
I instar	1.50-1.68	1.60 ± 0.05	0.20-0.25	0.22 ± 0.01
II instar	3.10-3.70	3.37 ± 0.17	0.35-0.40	0.36 ± 0.01
III instar	5.70-6.20	5.94 ± 0.18	0.80-0.92	0.86 ± 0.03
IV instar	12.20-13.10	12.80 ± 0.27	1.55-1.68	1.60 ± 0.04
V instar	15.50-16.50	16.01 ± 0.29	2.32-2.60	2.48 ± 0.08

Pre-pupa	13.15-13.75	13.48 ± 0.13	2.50-2.80	2.63 ± 0.08
Pupa	12.00 -13.50	12.83 ± 0.41	2.70-2.95	2.81 ± 0.08
Adult Male	9.70 – 12.80	11.05 ± 1.02	19.50-23.60	21.55 ± 1.45
Adult Female	9.50-13.30	11.85 ± 1.32	19.60-23.80	21.94 ± 1.42

n = 10

After the fifth instar, larvae entered a milky white pre-pupal stage with reduced feeding and activity (Fig. 3). This stage lasted 2.90 ± 0.20 days on ginger (Table 2), with mean length of 13.48 ± 0.13 mm and width of 2.63 ± 0.08 mm (Table 3). These results are close to Kasareddy (2017), who reported a prepupal duration of 3.15 ± 0.80 days. Pupation occurred within hollowed shoots. Pupae were obtect and elongated-oval, light brown initially and darker before adult emergence. The abdomen had ten segments with six spiracles on each side and a terminal dark brown spine; females were generally longer than males. Sex could be differentiated by genital opening position (females on the eighth segment; males on the ninth with two raised pads) (Fig. 3). Pupal length ranged from 12.00–13.50 mm (mean 12.83 ± 0.41 mm) and width ranged from 2.70-2.95 mm (mean 2.81 ± 0.08 mm) (Table 3). Mean pupal weights of males and females were 61.04 ± 3.13 and 71.43 ± 2.46 mg, respectively (Table 4). Pupal duration ranged from 7.00–8.00 days with a mean of 7.75 ± 0.29 days (Table 2). Satyanarayana and Arunakumara (2017) reported 9.49 to 12.01 days on ginger, and Kang *et al*. (2004) and Ganesha (2011) recorded 9 to 11 days. Such variations are likely due to differences in temperature and relative humidity.

Adults emerged mostly at night (7:00-10:00 PM) and showed clear nocturnal behaviour. Adults were medium-sized moths (19.50-23.80 mm width) with light yellowish bodies and several dark spots on the wings. Head, thorax and abdomen were distinct. Antennae and legs were brownish-yellow; two long, setaceous, multi-segmented antennae arose dorsally near the compound eyes. Wing margins had fine hair-like scales, and wing edges showed a golden tint with faint pale veins (Fig. 4). Male longevity ranged from 7.00-7.50 days (mean 7.20 ± 0.27 days) (Table 2), with body length 9.70-12.80 mm (mean 11.05 ± 1.02 mm), width 19.50–23.60 mm (mean 21.55 ± 1.45 mm) (Table 3) and weight 52.25–62.35 mg (mean 61.04 ± 3.13 mg) (Table 4). These values are comparable with Kasareddy (2017), who reported a male body length of 12.10 ± 0.79 mm. Female longevity ranged from 7.50–9.00 days (mean 7.90 ± 0.65 days) (Table 2), with body length 9.50-13.30 mm (mean 11.85 ± 1.32 mm), width 19.60-23.80 mm (mean 21.94 ± 1.42 mm) (Table 3) and weight 40.60–52.45 mg (mean 49.23 ± 2.81 mg) (Table 4), in agreement with Satyanarayana and Arunakumara (2017). Longevity differences may reflect diet and location effects.

Table 4. Weight of different stages of ginger shoot borer, *C. punctiferalis* reared on ginger

Life stages	Range (mg) / individual	Mean weight (mg)
I instar	8.50 - 11.50	9.07 ± 0.97
II instar	15.45 - 26.35	17.78 ± 3.20
III instar	42.40 - 52.70	44.8 ± 2.96
IV instar	76.20 - 86.55	77.54 ± 3.17
V instar	98.50 - 108.75	104.07 ± 2.33
Male pupa	52.25 - 62.35	61.04 ± 3.13
Female pupa	68.70 - 76.85	71.43 ± 2.46
Male adult	34.60 - 41.20	38.68 ± 1.75
Female adult	40.60 - 52.45	49.23 ± 2.81

n = 10

Fig 4. Male and female adults of *C. punctiferalis*

Pre-oviposition ranged from 2.50–3.00 days with a mean of 3.0 ± 0.50 days (Table 2). Females began laying eggs mainly at night, depositing eggs singly or in clusters on both leaf surfaces. This duration was longer than 1.21–1.65 days reported by Satyanarayana and Arunakumara (2017) and Kasareddy (2017), possibly due to differences in host nutrition affecting ovarian development. Oviposition lasted 2.00–2.50 days with a mean of 2.40 ± 0.22 days (Table 2), and egg laying was mostly nocturnal on both surfaces. These findings align with Kasareddy (2017) and Satyanarayana and Arunakumara (2017). Post-oviposition ranged from 2.50–3.00 days (mean 2.60 ± 0.22 days) (Table 2), comparable to Kasareddy (2017), with differences likely influenced by temperature and humidity. Fecundity ranged from 28–35 eggs per female with a mean of 31.00 ± 2.91 eggs (Table 2). This is much lower than the 80–111 eggs reported by Satyanarayana and Arunakumara (2017), likely due to differences in nutrition, physiological condition and environment. Total life cycle on ginger ranged from 40.00-46.50 days, with a mean of 42.50 ± 3.53 days in males and 43.50 ± 4.24 days in females (Table 2). This agrees with Kasareddy (2017), who recorded 40.10 ± 1.37 days for males and 42.50 ± 3.50 days for females, but differs from Stanley *et al.* (2009), who observed a shorter life cycle (32.02 days) on ginger.

Management of Shoot borer, *C. punctiferalis*

Before treatment application, shoot damage did not differ significantly among treatments (25.82 to 26.92 per cent). After the first spray, spinetoram 11.7 % SC (100 ml/acre) provided the best control, reducing shoot damage to 21.21, 16.73 and 14.63 per cent at 3, 7 and 15 DAS, respectively. Lambda-cyhalothrin 5 % EC, cartap hydrochloride 4 % G, chlorantraniliprole 0.4 % G and imidacloprid 70 % WG also reduced damage, while azadirachtin 1 % EC provided moderate suppression. Untreated plots recorded the highest damage at all intervals, reaching 32.27 % at 15 DAS. Following the second spray, the same pattern was evident. Spinetoram

Table 5. Bio-efficacy of newer insecticide molecules against *Conogethes punctiferalis* in ginger

Treatment	Dosage	DBS	Shoot damage (%)						Mean	Reduction over control (%)
			First spray			Second spray				
			3 DAS	7 DAS	15 DAS	3 DAS	7 DAS	15 DAS		
Lambda-cyhalothrin 5% EC	80 ml/ acre	26.62 (31.06)	22.42 (28.26)^{ab}	19.01 (25.83)^{b}	17.07 (24.36)^{a}	14.99 (22.73)^{b}	13.62 (21.61)^{b}	11.47 (19.76)^{b}	16.43	56.30
Cartap hydrochloride 4% G	10,000 g/acre	25.82 (30.54)	23.10 (28.71)^{abc}	20.30 (26.77)^{c}	16.03 (23.56)^{a}	15.67 (23.27)^{b}	13.25 (21.3)^{b}	12.9 (21.01)^{b}	16.87	55.13
Spinetoram 11.7% SC	100 ml/acre	26.01 (30.67)	21.21 (27.41)^{a}	16.73 (24.13)^{a}	14.63 (22.44)^{a}	14.31 (22.18)^{a}	11.9 (20.14)^{a}	10.08 (18.47)^{a}	14.81	60.61
Imidacloprid 70% WG	400 g/ acre	26.90 (31.23)	25.00 (28.99)^{bc}	24.10 (29.40)^{c}	26.74 (31.09)^{b}	17.46 (24.65)^{b}	15.47 (23.12)^{b}	13.65 (21.64)^{b}	20.40	45.74
Chlorantraniliprole 0.4% G	4,000 g/acre	26.92 (31.26)	24.30 (29.52)^{abc}	20.25 (26.73)^{b}	17.64 (24.79)^{b}	16.87 (24.2)^{b}	14.82 (22.6)^{b}	12.07 (20.29)^{b}	17.65	53.06

Azadirac htin 1% EC	400 ml/acre	26.12 (30.73)	25.33 (30.20)[bc]	26.15 (30.74)[cd]	27.58 (31.63)[b]	21.7 (27.71)[b]	15.29 (22.97)[b]	14.42 (22.27)[b]	21.74	42.18
Untreated check	-	26.82 (30.64)	27.99 (31.93)[c]	29.85 (33.10)[d]	32.27 (34.57)[b]	41.46 (40.05)[c]	44.23 (41.66)[c]	49.82 (44.9)[c]	37.60	-
S.Em±		-	1.12	1.04	1.54	1.51	1.44	1.46	-	-
P- value		-	0.002	0.025	0.0005	2.92E-05	2.47E-06	2.47E-06	-	-
CD @ 5%		NS	3.47	3.23	4.76	4.66	4.43	4.5	-	-
C.V. (%)		8.93	8.06	8.13	9.73	9.92	10.05	10.51	-	-

Note: DBS- Days before spray, DAS- Days after spray; Figures in parenthesis are arcsine transformed values; Means in the column followed by the same alphabet do not differ significantly by DMRT (P=0.05)

again recorded the lowest damage at 3, 7 and 15 DAS (14.31, 11.90 and 10.08 per cent, respectively), and was significantly superior to other treatments. Lambda-cyhalothrin 5 % EC and cartap hydrochloride 4 % G were the next best options. Untreated plots showed markedly higher damage, reaching 49.82 per cent at 15 DAS (Table 5). Across two sprays, mean shoot damage was lowest in spinetoram (14.81 %), followed by lambda-cyhalothrin (16.43 %), cartap hydrochloride (16.87 %), chlorantraniliprole (17.65 %), imidacloprid (20.40 %) and azadirachtin (21.74 %). Untreated control recorded a mean of 37.60 per cent damage. In terms of reduction over control, spinetoram achieved the highest reduction (60.61 %), followed by lambda-cyhalothrin (56.30 %), cartap hydrochloride (55.13 %) and chlorantraniliprole (53.06 %). Imidacloprid and azadirachtin showed lower reductions of 45.74 and 42.18 per cent, respectively (Table 5).

Earlier chemical control of ginger shoot borer relied on pesticides such as monocrotophos, malathion, parathion and carbaryl, many of which are now banned in India (Kumaresan *et al*., 1978; Mandal *et al*., 1978; Mogal *et al*., 1980; Regupathy, 1983). Bacillus thuringiensis formulations combined with malathion were also reported effective (Devasahayam, 2000). The present study indicated clear differences in insecticide efficacy against *C. punctiferalis* on ginger. Spinetoram 11.7 % SC produced the highest reduction in shoot damage (60.61 %), which may be attributed to its spinosyn mode of action, translaminar activity and residual effect. Lambda-cyhalothrin 5 % EC ranked next (56.30 %), likely due to rapid knockdown, although persistence may be reduced by photodegradation (Narayanamma *et al*., 2013; Satyanarayana and Arunakumara, 2017; Chethan *et al*., 2017). Cartap hydrochloride 4 % G (55.13 %) provided substantial control through systemic and contact activity across pest stages. Chlorantraniliprole 0.4 % G (53.06 %) performed consistently, reflecting its action on ryanodine receptors, although mortality develops more slowly (Chethan *et al*., 2017). Imidacloprid 70 % WG was less effective (45.74 %), consistent with its greater activity against sap feeders rather than lepidopteran borers (Kumar *et al*., 2019). Azadirachtin 1 % EC was least effective, aligning with previous reports that botanicals alone are often insufficient against shoot borers (Rajkumar *et al*., 2003), although some studies have noted small but measurable benefits of bio-pesticides (Rashmi *et al*., 2020). Overall, spinetoram and lambda-cyhalothrin appear most promising for shoot borer control in ginger, while botanicals and neonicotinoids may need integration in an IPM programme for reliable suppression.

CONCLUSION

The present study elucidates the developmental biology of *C. punctiferalis* on ginger and evaluates the comparative efficacy of selected insecticides for its management. Under laboratory conditions, ginger supported complete development of the pest, though prolonged larval duration, reduced larval size, and increased mortality indicated that it is a comparatively suboptimal host. Such delayed development may limit rapid population buildup but simultaneously prolong larval exposure in the field, potentially influencing pest-natural enemy interactions. Bio-efficacy trials clearly demonstrated that spinetoram 11.7% SC was the most effective treatment in minimizing shoot damage and sustaining control, followed by lambda-cyhalothrin 5% EC. Other insecticides provided moderate to low levels of protection, while untreated plots suffered severe damage, underscoring the economic threat posed by C. punctiferalis to ginger cultivation. Overall, the findings contribute valuable insights into the pest's biology on ginger and support the integration of spinetoram-based interventions within an integrated pest management (IPM) strategy for effective and sustainable control.

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AUTHORS CONTRIBUTION

AB, PS, SD: conceptualization, designing and implementation of the experiments and MS preparation implementation of the experiments; MHB and B: planning, supervising and formal analysis and MS finalisation

CONFLICT OF INTEREST

The authors do not have any conflict of interest with respect to the content of the article.

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