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Lethal and sub-lethal effects of fipronil on growth and development of okra shoot and fruit borer (*Earias vitella*: Noctuidae: Lepidoptera)

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Abstract

The shoot and fruit borer *Earias vitella* (Fabricius) is a major pest affecting okra (*Abelmoschus esculentus*), causing significant yield and quality losses across all crop stages. Chemical control remains a primary strategy, with fipronil, a phenyl pyrazole insecticide, being widely used. This study evaluated the lethal (LC_{50}) and sub-lethal (LC_{15} and LC_{10}) effects of fipronil on the growth and development of *E. vitella* under laboratory conditions at ICAR-IIVR, Varanasi, using diet incorporation bioassays. The LC_{50} value was determined to be 4.844 ppm, while LC_{15} and LC_{10} were 0.068 ppm and 0.025 ppm, respectively. Sub-lethal doses significantly influenced key biological parameters, including prolonged larval and pupal durations, reduced larval and pupal weight and length, increased mortality, reduced pupation and adult emergence rates, and decreased fecundity. Growth index and adult longevity were also notably reduced compared to the control. These findings suggest that, beyond direct lethality, sub-lethal exposures to fipronil can impair developmental and reproductive fitness in *E. vitella*, potentially offering extended pest suppression benefits. The study highlights the importance of incorporating sub-lethal effects into insecticide efficacy assessments for integrated pest management (IPM) strategies in okra cultivation.

Keywords: *Earias vitella*, LC_{50}, okra, Sub lethal

Introduction

Vegetables are fresh, edible parts of herbaceous plants. They are a vital food that is very helpful in preserving health and preventing illness. They include beneficial food components that the body may effectively use to strengthen and heal itself. Vegetables are beneficial for preserving the body's alkaline reserves. Their high levels of carbohydrates, vitamins, and minerals make them valuable. Vegetables come in several varieties. They could be edible seeds, fruits, stems, leaves, or roots. Every vegetable makes a unique contribution to diet (Robinson, 1990) [3]. Due to the nation's increased vegetable output, the number of vegetables available per person increased from 264 grams per day in 2004-05 to 355 grams per person per day in 2011-16.

India ranks first in the production of peas (*Pisum sativum*) and okra (*Abelmoscus esculentus*) and second in the production of tomatoes (*Solanum lycopersicum*), cauliflower (*Brassica oleracea*), potatoes (*Solanum tuberosum*), onions (*Allium cepa*), and brinjal (*Solanum melongena*). The nation's primary cereals can be supplemented with vegetables, which are a rich and relatively inexpensive source of proteins, carbs, vitamins, and minerals. Vegetables provide us with a variety of chemicals that our bodies need for development, reproduction, and health maintenance.

Earias vitella (Fabricius) (Lepidoptera: Noctuidae) is a shoot and fruit borer that is a major pest of lepidopterans that is found throughout North Africa, India, Pakistan, and several other countries. It mostly affects crops in the Malvaceae family, including cotton (Nada *et al.* 2010; Kumar *et al.* 2014) [4, 5] and okra (Aziz *et al.*, 2011) [2]. It has a wide host range. These insects directly harm the delicate shoots and fruits of okra, causing the afflicted plants to produce smaller, malformed fruits (Rahman *et al.*, 2013) [6]. Okra is attacked by shoot and fruit borers at every stage of growth, which seriously impairs the crop's quantity and quality (Shah *et al.*, 2001) [7]. Fruit loss from *Earias spp.* infestations ranges from 21.00% to 91.58% in different okra varieties. They damage the crop throughout vegetative and the reproductive stages, thus causing ample decline in yield (Kataria and Singh 2021) [8].

Fipronil, which is a novel insecticide of the phenyl pyrazole class, is 5-amino-1-(2,6-dichloro-α,α,α-trifluoro-p-tolyl)-4-trifluoromethylsulfinyl pyrazole-3-carbonitrile. Rhone-Poulenc Ag Company (now Bayer Crop Science) produced it for the first time in 1987, and the product was introduced in 1993 (Tomlin, 2000). It inhibits the normal activity of GABA by targeting gamma-aminobutyric acid (GABA) receptors, which are the main neurotransmitters in insects (Sammelson *et al.*, 2004) [9].

Fipronil is a very effective compound; piercing, sucking, and chewing insect pests that are resistant to other chemicals like pyrethroids, organophosphates, and carbamates may often be controlled with just a few grams of the active ingredient per hectare.

While fipronil is commonly used to control various pests, including *E. vitella*, its potential impacts on the pest's biology beyond simple mortality are not well-documented. Understanding the lethal effects of these insecticides is critical for evaluating its direct efficacy in controlling *E. vitella* populations, but equally important is examining the sub-lethal effects, which can influence pest behaviour, reproduction, and overall pest dynamics. Sub-lethal exposure to insecticides can lead to changes in feeding patterns, decreased reproductive success, altered development rates, and increased pest resistance over time, even in the absence of immediate mortality. Given the importance of *E. vitella* as a pest of okra, it is essential to understand how sub-lethal doses of fipronil and novaluron might affect pest survival and fitness in the long term. This study will provide crucial insights into the broader impact of insecticide application, helping to inform future pest control practices and contribute to the sustainable management of *E. vitella* in okra cultivation.

Materials & Method

Collection and rearing of fruit and shoot borer

Larvae of *Earias vitella* were collected from unsprayed okra fields of ICAR- Indian Institute of Vegetable Research, Varanasi and maintained in the laboratory under controlled conditions in transparent plastic jars (25±2 °C, 60±5% relative humidity). The larvae were provided with fresh okra fruit until they pupated. Once pupation occurred, the pupae were transferred to a plastic box lined with tissue paper. Upon emergence, the adult moths were fed a 10% sugar solution. Butter paper strips were placed in the rearing cage for egg laying. The eggs were collected and transferred to separate plastic jars (1 kg capacity). After hatching, the second instar larvae of *E. vitella* were used for bioassays and biological studies. Precautions: The utmost hygienic conditions were kept in rearing facilities.

Artificial diet composition and preparation

Earias vitella were reared on artificial diet. An artificial diet was developed for mass rearing of the *Earias vitella* in environmentally controlled conditions. The ingredients for 1l of diet ingredients consisting of soybean flour (*Glycine max*) (60.0 g), chickpea flour (*Cicer arietinum var. kabuli*) (58.0 g), wheatgerm (16.0 g), dried yeast powder (16.0 g), casein (8.0 g), L-ascorbic acid (2.4 g), cholesterol (0.4 g), methyl-p-hydroxybenzoate (0.4 g), sorbic acid (2.4 g), *streptomycin* sulphate (0.4 g), agar-agar (16.0 g) and distilled water (820 ml). The insect rearing and mass multiplication was done using the methodology given by (Gupta *et al.*, 2005) [11].

Table 1. Composition of artificial diet for rearing *Earias vitella* larvae

Groups	Ingredients	Quantity (g)
Fraction A	Soybean flour (*Glycine max*)	60.0
	Chickpea flour (*Cicer arietinum* var. *kabuli*)	58.0
	Wheatgerm (Wheatgerm, Bakers, India Ltd.)	16.0
Fraction B	Dried yeast powder (Tower Brand, The Indian Yeast Co. Ltd.)	16.0
	Casein (Central Drug House, Ltd.)	8.0
	L-Ascorbic acid (SDS, s.d. Fine Chem Ltd.)	2.4
	Cholesterol (SDS, s.d. Fine Chem Ltd.)	0.4
Fraction C	Methyl-p-hydroxybenzoate (LOBA Chemie)	0.4
	Sorbic acid (SDS, s.d. Fine Chem Ltd.)	2.4
	Streptomycin sulphate (Indian Drugs and Pharmaceuticals Ltd.)	0.4
Fraction D	Agar-agar (Qualigens Fine Chemicals)	16.0
	Distilled water	820 ml

The ingredients for the artificial diet of *E. vitella* are provided in Table 3.3 The components of fraction 'A' were thoroughly mixed in a blender with 400 ml of lukewarm distilled water. Agar-agar (fraction 'D') was dissolved in 420 ml of lukewarm water, then boiled in a Borosil beaker. Once cooled to approximately 50° C, it was added to fraction 'A' in the blender. This mixture was blended at high speed for about 1 minute. Next, the ingredients of fractions 'B' and 'C' were added, and the mixture was well stirred. The resulting warm, homogeneous diet mixture was poured into sterilized 15 x 2.5 cm Petri dishes and allowed to cool. After solidifying at room temperature (25-30 °C), the diet was refrigerated.

Toxicity Bioassay

To find out LC_{50} bioassay experiments was performed using the diet incorporation method. Different concentration of insecticides were added to the artificially prepared diet in the bioassay tray on which insects were reared and evaluated further. The experiment was replicated three times. Mortality was noted after 24 hours after treatment. Lethal and sublethal effects against *E. vitella* larvae was evaluated using a lethal and sublethal concentration calculated from the toxicity experiment (Gulzar *et al.* 2019) [12].

Statistical analysis

Mortality counts were taken 24 hours after treatment. The moribund insects were considered as dead. The mortality data so obtained were converted into corrected per cent mortality using the Abbott's formula (Abbott, 1925) as given below:

P" = P'-C/100-C X 100

Where,
P" = Corrected per cent mortality in the test insect
P' = Observed per cent mortality in the test insect
C = Per cent mortality in the control

The corrected per cent mortality data thus obtained were subjected to the probit analysis (Finney, 1971) [13] to compute LC_{50} value for each insecticide.

Assessing effect of sub lethal dose

The lethal and sublethal effects of fipronil and novaluron on *E. vitella* larvae were assessed using lethal and sublethal concentrations of fipronil and novaluron determined from the toxicity experiment using diet incorporation method.

To study the lethal and sub-lethal effect on growth, lethal and sub-lethal concentration of fipronil and novaluron, were tested against *E. vitella*. The sublethal dose (LC_{10} and LC_{15}) of each insecticide was applied using the diet incorporation method. Second instar larvae were carefully transferred to bioassay tray containing toxicant incorporated artificial diet using a camel hair brush. Three replications of each treatment were maintained, with 15 larvae per replication. The bioassay trays were placed in a BOD incubator set at 28±2 °C with 70±5% relative humidity. After 24 hours of exposure, the larvae were transferred to jars containing fresh okra fruits, and observations were made until the completion of the life cycle.

Observations were made on larval length, weight of mature larvae, larval longevity, and mortality. Similar data were also collected for pupal length, weight, longevity, and mortality. Pupae were weighed at two days of age to ensure they had hardened sufficiently to avoid damage during handling. Each individual pupa was properly labelled and placed in small jars for further observation, including the time required for adult emergence, percentage of adult emergence, and adult longevity. The sex of the *E. vitella* pupae was determined by examining the cocoon, as described by Gupta (1978) [14], who noted that male cocoons have a distinct knob at the antero-dorsal end, which is absent in females. Moths that emerged from larvae exposed to sublethal doses of fipronil were observed to record the longevity of both males and females. These moths were placed in an egg-laying chamber to assess the fecundity of individual females. The results were compared to the control group.

Results and Discussion

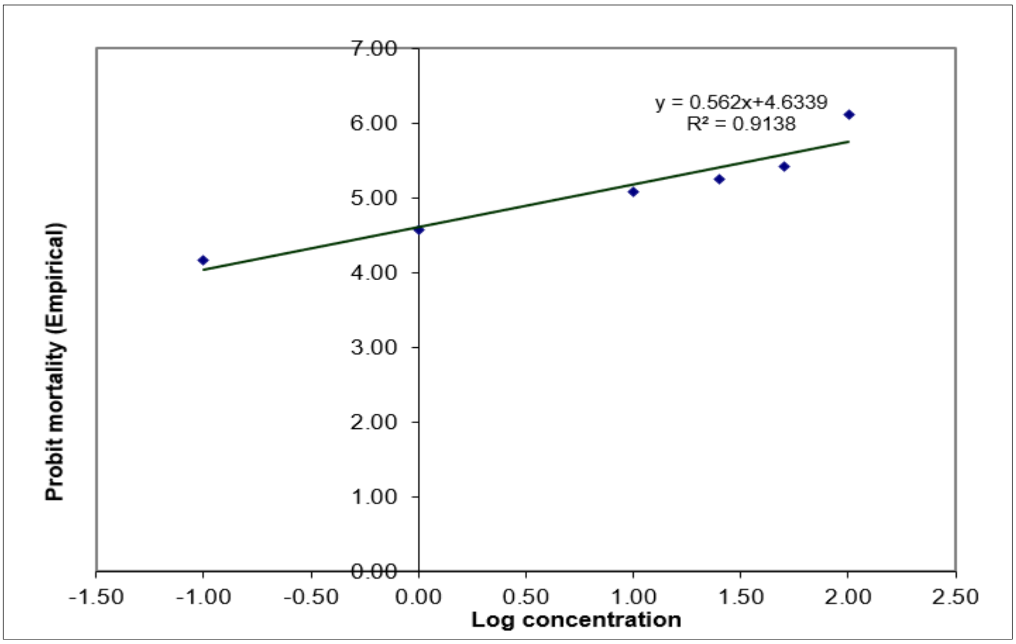
Calculation of LC_{50}, LC_{15} and LC_{10} of fipronil against *Earias vitella*.

The toxicity of fipronil and novaluron by bio-assaying second instar larvae of *Earias vitella* was determined in laboratory by artificial diet incorporation method using Mekapogu, A.R (2021) Finney's probit analysis spreadsheet calculator (Version 2021). LC_{50} value of fipronil was found to be 4.844 ppm. The value of LC_{15} and LC_{10} of fipronil were calculated 0.068 ppm and 0.025 ppm respectively (Table 2).

Table 2; Comparative toxicity of fipronil and novaluron against second instar larvae of *E. vitella* by diet incorporation method

Insecticides	Regression equation	LC_{50} (ppm)	Fiducial limit	LC_{15} (ppm)	Fiducial limit	LC_{10} (ppm)	Fiducial limit	χ2 (df)	Slope
Fipronil	0.562x+4.6339	4.844	1.239-18.939	0.068	0.017- 0.266	0.025	0.006-0.097	0.996(4)	0.0571

Y= probit kill; X=log (concentration in per cent x 10^3); LC_{50} = concentration (parts per million) calculated to give 50 per cent mortality.



Fipronil

Fig 1: Standard doses mortality curve for second instar larvae of *E.vitella* (Artificial diet incorporation method)

Effect of lethal and Sub-lethal doses on growth and development of *Earias vitella.*

The effect of lethal and sublethal doses (LC_{50}, LC_{15}, LC_{10}) of insecticides viz. fipronil and novaluron was assessed on the basis of their effect on the larval period, larval weight, larval length, larval mortality, per cent pupation, pupal period, pupal weight, pupal length, pupal mortality, per cent adult emergence, adult longevity, fecundity and growth index.

Effect of lethal and Sub-lethal doses on Larave

Larval longevity

Fipronil

Effect of lethal and sub lethal doses of fipronil on larval longevity presented in Table 4.15. The longest larval period was 16.06 days in T_1 (LC_{50}), followed by 13.4 days in T_3 (LC_{10}), 12.66 days in T_4 (control), and 12.43 days in T_2 (LC_{15}). Both T_3 (LC_{10}) and T_1 (LC_{50}) had significantly longer larval periods compared to T_2 (LC_{15}) and T_4 (control).

Table 3: Effect of lethal and Sub-lethal doses on Larval longevity (Days)

Larval longevity (days)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	16.06	-26.84
T_2 (LC $_{15}$)	12.43	-5.78
T_3(LC $_{10}$)	13.4	1.84
T_4 (Control)	12.66	0
C.D.	0.428	
SE(m)	0.129	

Larval weight

Fipronil

Effect of lethal and sub lethal doses of fipronil on larval weight presented in Table 4.16. The highest mean weight of 0.089 g was recorded in T_4 (control) which is reduced to 0.079 g in T_3 (LC_{10}), 0.077 g in T_2 (LC_{15}) and 0.074 g in T_1 (LC_{50}). T_1 (LC_{50}), T_2 (LC_{15}) and T_3 (LC_{10}) were significantly at par with each other.

Table 4: Effect of lethal and Sub-lethal doses on Larval weight (g)

Larval weight (g)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	0.074	16.85
T_2 (LC $_{15}$)	0.077	13.48
T_3(LC $_{10}$)	0.079	11.23
T_4 (Control)	0.089	0
C.D.	0.008	
SE(m)	0.003	

Larval length

Fipronil

Effect of lethal and sub lethal doses of fipronil on larval length presented in Table 4.17. In T_1 (LC_{50}) and T_2 (LC_{15}) there is significant reduction in length 14.98 mm and 15.98 mm respectively, whereas there was no significant reduction 15.96 mm in T_3 (LC_{10}) as compared to 17.07 mm in T_4 (control).

Table 5: Effect of lethal and Sub-lethal doses on Larval length (mm)

Larval length (mm)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	14.98	12.24
T_2 (LC $_{15}$)	15.98	6.36
T_3(LC $_{10}$)	16.24	4.84
T_4 (Control)	17.07	0
C.D.	0.991	
SE(m)	0.299	

Larval mortality

Fipronil

Effect of lethal and sub lethal doses of fipronil on larval mortality presented in Table 4.18. The maximum mortality is 41.66 per cent in T_1 (LC_{50}), followed by 38.33 per cent in T_2 (LC_{15}), 36.66 per cent in T_3 (LC_{10}). Significantly lower mortality was found 6.66 per cent in T_4 (control). It was observed that 41.66 per cent in T_1 (LC_{50}), 38.33 per cent in T_2 (LC_{15}) and 36.66 per cent T_3 (LC_{10}) were significantly at par.

Table 6: Effect of lethal and Sub-lethal doses on Larval mortality (%)

Larval mortality (%)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	41.66	-524.97
T_2 (LC $_{15}$)	38.33	-474.96
T_3(LC $_{10}$)	36.66	-449
T_4 (Control)	6.66	0
C.D.	14.603	
SE(m)	4.41	

Effect of lethal and Sub-lethal doses on Pupa

Effect on pupation

Fipronil

Effect of lethal and sub lethal doses of fipronil on pupation percentage presented in Table 4.19. Fipronil doses cause significant reduction in percent pupation when compared to control. Maximum pupation percent was found 90.54 per cent in T_4 (control) followed by 60.47 per cent in T_3 (LC_{10}), 51.94 per cent in T_2 (LC_{15}) and minimum 51.25 per cent in T_1 (LC_{50}). It was observed that 51.94 per cent in T_1 ($LC_{.50}$) and 51.25 per cent T_2 (LC_{15}) were significantly at par.

Table 7: Effect of lethal and Sub-lethal doses on Pupation (%)

Pupation (%)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	51.25	43.39
T_2 (LC $_{15}$)	51.94	42.62
T_3(LC $_{10}$)	60.47	33.21
T_4 (Control)	90.54	0
C.D.	3.11	
SE(m)	0.94	

Pupal longevity

Fipronil

Effect of lethal and sub lethal doses of fipronil on pupal longevity presented in Table 4.20. Pupal longevity differs from each other with maximum pupal period 11.57 days in T_1 (LC_{50}) followed by 9.59 days in T_2 (LC_{15}), 9.39 days in T_3 (LC_{10}) and minimum 7.68 days in T_4 (control). It was observed that 9.59 days in T_2 (LC_{15}) and 9.39 days in T_3 (LC_{10}) were significantly at par with each other.

Table 8: Effect of lethal and Sub-lethal doses on Pupal longevity (Days)

Pupal longevity (Days)		
Treatment	Fipronil	Increment or decrement over control (%)
T_1 (LC $_{50}$)	11.57	-50.63
T_2 (LC $_{15}$)	9.59	-24.86
T_3(LC $_{10}$)	9.39	-22.25
T_4 (Control)	7.68	0
C.D.	1.952	
SE(m)	0.589	

Pupal weight
Fipronil

Effect of lethal and sub lethal doses of fipronil on pupal weight presented in Table 4.21. The lowest pupal weight was found 0.057 g in T_1 (LC_{50}) followed by 0.059 g in T_2 (LC_{15}), 0.066 g in T_3 (LC_{10}) and 0.069 in T_4 (control). There is significant reduction in 0.057 g in T_1 (LC_{50}) and 0.059 g in T_2 (LC_{15}) over control. It was observed that 0.057g in T_1 (LC_{50}), 0.059g in T_2 (LC_{15}) and 0.066g T_3 (LC_{10}) were significantly at par with each other.

Table 9: Effect of lethal and Sub-lethal doses on Pupal weight (g)

Pupal weight (g)		
Treatment	Fipronil	Increment or decrement over control (%)
T_1 (LC $_{50}$)	0.057	17.39
T_2 (LC $_{15}$)	0.059	14.49
T_3(LC $_{10}$)	0.066	4.32
T_4 (Control)	0.069	0
C.D.	0.009	
SE(m)	0.003	

Pupal length
Fipronil

Effect of lethal and sub lethal doses of fipronil on pupal length presented in Table 4.22. The pupal length reduced significantly in treatments when compared to 10.68 mm in T_4 (control). Minimum pupal length was observed in 8.39 mm T_1 (LC_{50}) followed by 9.44 mm in T_2 (LC_{15}) and 9.8 mm in T_3 (LC_{10}). It was observed that 9.44 mm in T_2 (LC_{15}) and 9.8 mm in T_3 (LC_{10}) were significantly at par with each other.

Table 10: Effect of lethal and Sub-lethal doses on Pupal length (mm)

Pupal length (mm)		
Treatment	Fipronil	Increment or decrement over control (%)
T_1 (LC $_{50}$)	8.39	21.41
T_2 (LC $_{15}$)	9.44	11.61
T_3(LC $_{10}$)	9.8	8.23
T_4 (Control)	10.68	0
C.D.	0.669	
SE(m)	0.202	

Pupal mortality
Fipronil

Effect of lethal and sub lethal doses of fipronil on pupal mortality presented in Table 4.23. The highest mortality was found 24.74 per cent in T_1 (LC_{50}) followed by 22.11 per cent in T_2 (LC_{15}) and 22.01 per cent in T_3 (LC_{10}). All these treatments recorded significantly higher mortality than 12.58 percent in T_4 (control).

Table 11: Effect of lethal and Sub-lethal doses on Pupal mortality (%)

Pupal mortality (%)		
Treatment	Fipronil	Increment or decrement over control (%)
T_1 (LC $_{50}$)	24.74	-75.75
T_2 (LC $_{15}$)	22.11	-74.96
T_3(LC $_{10}$)	22.01	-96.68
T_4 (Control)	12.58	0
C.D.	2.316	
SE(m)	0.699	

Effect of lethal and Sub-lethal doses on adult
Effect on adult emergence
Fipronil

Effect of lethal and sub lethal doses of fipronil on adult emergence presented in Table 4.24. The lowest adult emergence was found 72.73 in T_1 (LC_{50}) followed by 73.91 per cent in T_2 (LC_{15}), 77.73 per cent in T_3 (LC_{10}) which are significantly lower than 86.14 per cent T_4 (control). T_1 (LC_{50}) 72.73 per cent and T_2 (LC_{15}) 73.91 per cent were significantly at par with each other.

Table 12: Effect of lethal and Sub-lethal doses on adult emergence (%)

Adult emergence (%)		
Treatment	Fipronil	Increment or decrement over control (%)
T_1 (LC $_{50}$)	72.73	15.56
T_2 (LC $_{15}$)	73.91	14.09
T_3(LC $_{10}$)	77.35	10.19
T_4 (Control)	86.14	0
C.D.	3.869	
SE(m)	1.168	

Adult longevity
Male longevity
Fipronil

Effect of lethal and sub lethal doses of fipronil on male longevity presented in Table 4.25. Significantly less male longevity was observed 3.13 days in T_1 (LC_{50}), 3.39 days in T_2 (LC_{15}) and 3.13 days in T_3 (LC_{10}) as compared to 5.35 days in T_4 (control). It was observed that T_1 (LC_{50}), T_2 (LC_{15}) and T_3 (LC_{10}) were significantly at par with each other.

Table 13: Effect of lethal and Sub-lethal doses on Male longevity (Days)

Male longevity (Days)		
Treatment	Fipronil	Increment or decrement over control (%)
T_1 (LC $_{50}$)	3.13	41.47
T_2 (LC $_{15}$)	3.39	36.67
T_3(LC $_{10}$)	3.62	32.37
T_4 (Control)	5.35	0
C.D.	1.137	
SE(m)	0.343	

Female longevity
Fipronil

Effect of lethal and sub lethal doses of fipronil on female longevity presented in Table 4.26. Significantly lower female adult longevity was recorded 7.33 days in T_1 (LC_{50}), 7.75 days in T_2 (LC_{15}) and 7.76 days in T_3 (LC_{10}) when compared to 9.64 days in T_4 (control). It was observed that T_1 (LC_{50}), T_2 (LC_{15}) and T_3 (LC_{10}) were significantly at par with each other.

Table 14: Effect of lethal and Sub-lethal doses on Female longevity (Days)

Female longevity (Days)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	7.33	23.89
T_2 (LC $_{15}$)	7.75	19.53
T_3(LC $_{10}$)	7.76	19.42
T_4 (Control)	9.64	0
C.D.	0.513	
SE(m)	0.155	

Fecundity
Fipronil
Effect of lethal and sub lethal doses of fipronil on fecundity presented in Table 4.27. The adult fecundity significantly reduced to 83.38 egg/ female in T_1 ($LC_{.50}$), 93.33 eggs/ female in T_2 (LC_{15}) and 103.75 eggs/ female in T_3 (LC_{10}) when compared to 149.08 eggs/female in T_4 (control).

Table 15: Effect of lethal and Sub-lethal doses on Fecundity (Eggs/female)

Fecundity (Eggs/female)		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	83.38	44.06
T_2 (LC $_{15}$)	93.33	37.39
T_3(LC $_{10}$)	103.75	30.40
T_4 (Control)	149.08	0
C.D.	8.008	
SE(m)	2.418	

Effect on growth index
Fipronil
The studies on growth and development of *E. vitella* revealed the lower growth index in all the treatments (T_1, T_2 and T_3) compared to T_4 (control). The data presented in Table 4.28 shows higher growth index 7.3 in T_4 (control) as compared to and 3.51 in T_1 (LC_{50}), 4.22 in T_2 (LC_{15}) and 4.32 in T_3 (LC_{10}). It was observed that growth index 4.22 in (T_2) and 4.32 in (T_3) were significantly at par with each other.

Table 16: Effect of lethal and Sub-lethal doses on Growth index

Growth index		
Treatment	**Fipronil**	**Increment or decrement over control (%)**
T_1 (LC $_{50}$)	3.51	51.91
T_2 (LC $_{15}$)	4.22	42.09
T_3(LC $_{10}$)	4.32	40.78
T_4 (Control)	7.3	0
C.D.	0.462	
SE(m)	0.139	

Kale *et al.*, (2002) evaluated the toxicity of fipronil on neonate (0-10-hour-old) larvae of *Earias vittella* using fruit-dip bioassays. They reported LC_{50} value of 0.115 ppm for fipronil at 96 hours post-treatment. It differs from, our study determined LC_{50} value of 4.844 ppm at 24 hours post-treatment for second-instar larvae. The higher LC_{50} value in our study likely reflects the shorter exposure duration and the use of later-stage larvae, as neonates exhibit greater susceptibility to insecticides. Generally, mortality values decrease with prolonged exposure or when later larval instars are tested, due to cumulative toxic effects and reduced sensitivity in older larvae. Saleem *et al.*, (2024) reported the LC_{50} values of fipronil against third instar *Spodoptera frugiperda* as 111.8 ppm, 50.75 ppm, and 20.5 ppm after 24, 48, and 72 hours of exposure, respectively. The relatively high LC_{50} values may be attributed to the comparatively greater resistance of *S. frugiperda* to fipronil than that observed in *Earias vitella*.

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