

**EFFICACY OF NEWER INSECTICIDES AGAINST PSEUDOSTEM  
WEEVIL, *Odoiporus longicollis* (Olivier) OF BANANA**

by

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(Reg. No.16/163)

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**

**COLLEGE OF AGRICULTURE, KOLHAPUR**

**MAHATMA PHULE KRISHI VIDYAPEETH  
RAHURI-413722, DIST-AHMEDNAGAR  
MAHARASHTRA, INDIA**

**2018**

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A Thesis submitted to the  
**MAHATMA PHULE KRISHI VIDYAPEETH,  
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MAHARASHTRA, INDIA.**

In partial fulfilment of the requirements for the degree

of

**MASTER OF SCIENCE (AGRICULTURE)**

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MAHARASHTRA, INDIA**

**2018**



## CANDIDATE'S DECLARATION

I hereby declare that this thesis or part  
there of has not been submitted  
by me or other person to any  
other University or Institute  
for a Degree or  
Diploma

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## **CERTIFICATE**

This is to certify that the thesis entitled. “**EFFICACY OF NEWER INSECTICIDE AGAINST PSEUDOSTEM WEEVIL, *Odoiporus longicollis* (Olivier) OF BANANA**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **MR. KHARE ROHAN RAJARAM** under my guidance and supervision of and that no part of the thesis has been submitted for any other degree or diploma.

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Place: Kolhapur

Khare R.R.

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**LIST OF ABBREVIATIONS AND SYMBOLS**

a. i.	:	Active Ingredient
C.D.	:	Critical Difference
°C	:	Degree Celsius
cm	:	Centimeter
C. V.	:	Coefficient of Variance
cv.	:	Cultivar
DAT	:	Days After Transplanting
EC	:	Emulsifiable Concentrate
<i>et al.</i>	:	and others
etc.	:	Etcetera
Fig.	:	Figure
g	:	Gram
G	:	Granule
H	:	Hour
ha	:	Hectare
i.e.	:	That is
ICBR	:	Incremental cost benefit ratio
IPM	:	Integrated Pest Management
IU	:	International Unit
L	:	Liter
kg	:	Kilogram
Max	:	Maximum
mg	:	Milligram
Min.	:	Minimum
ml	:	Milliliter
MSW	:	Meteorological Standard Week

MT	:	Metric Ton
M.W.	:	Meteorological Week
No.	:	Number
nos.	:	Numbers
ppm	:	Parts per million
q	:	Quintal
RH	:	Relative Humidity
SC	:	Soluble Concentrate
SG	:	Soluble Granule
SL	:	Soluble Liquid
SP	:	Soluble Powder
SW	:	Standard Week
t	:	Ton
V	:	Volume
<i>Var.</i>	:	Variety
<i>Viz</i>	:	Namely
%	:	Per cent
S.E.	:	Standard Error
EDC	:	Emulsifiable Dispersible Concentrate
WG	:	Wettable Granule
WSC	:	Water Soluble Concentrate
WP	:	Wettable Powder
/	:	Per
@	:	At the rate of

## ABSTRACT

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### EFFICACY OF NEWER INSECTICIDES AGAINST PSEUDOSTEM WEEVIL, *Odoiporus longicollis* (Olivier) OF BANANA

*by*

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Research guide	:	Dr. Pandurang. B. Mohite
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Field experiment entitled “Efficacy of newer insecticides against pseudostem weevil, *Odoiporus longicollis* (Olivier) of Banana” was conducted during *Rabi* season of 2017-18 with nine treatments, replicated thrice, in the ‘Randomized Block Design’ with gross plot size 21 m x 21 m and net plot size 20 m x 20 m on the farmers field, located at Mangaon, Taluka – Chandgad, Kolhapur (Maharashtra) with the objectives., to study the seasonal incidence of pseudostem weevil of banana, to study biology of pseudostem weevil of banana, to study efficacy of newer insecticides against pseudostem weevil of banana under laboratory condition and to study efficacy of newer insecticides against pseudostem weevil of banana under field condition.

The treatments comprised of triazophos 40 EC @4.28 ml/lit, imidacloprid 17.8 EC @ 0.5 ml/lit, neemazal @10 ml/lit, cyantraniliprole 10.26 OD @ 0.5 ml/lit, beta-cyfluthrin+ imidacloprid 300 OD @1.5 ml/lit, *Beauveria bassiana* @ 8gm/lit, chlorpyrifos 20 EC@ 2.5 ml/lit, *M. anisopliae* @8gm /lit, untreated control and same treatments followed under laboratory experiment.

The studies on seasonal incidence clearly indicated that initial infestation of 0.50 per cent first appeared in the 11<sup>th</sup> MW corresponding to last week of March, 2017 when the average minimum and maximum temperature varied from 18 °C to 24 °C to 1.40 per cent in the 12<sup>th</sup> MW corresponding to 2<sup>nd</sup> week of April when the average minimum and maximum temperature varied from 18 °C to 25 °C and average minimum and maximum relative humidity ranged from

78% to 82 %, respectively with 00 mm rainfall. Then, infestation gradually increased up to September, 2017 and declined gradually during winter. Subsequently, infestation reached its first peak in 34<sup>th</sup> MW corresponding to 37<sup>th</sup> week of September, 2017 (20%) when the average minimum and maximum temperature varied from 17.5 °C to 30.7 °C and average minimum and maximum relative humidity ranged from 75 % to 81 %, respectively with 2.45 mm rainfall. The infestation was noticed up to end of November. Infestation also observed after harvesting of banana when these plants were not removed from the field and considered as source of infestation to the next season.

The adult weevil mate during the night hours under lab condition. The incubation period varied from 3 - 4 (mean  $3.6 \pm 0.54$ ) days. The grub passed through five instars to complete the larval period. The total larval period varied from 30 to 35 (Mean  $32.2 \pm 1.92$ ) days. The prepupal period lasted for 3 to 5 (mean  $4.1 \pm 0.89$ ) days. The pupal period lasted for 17 to 20 (mean  $18.6 \pm 1.34$ ) days. The total life cycle of *O. longicollis* from egg to adult emergence varied from 53.0 to 65.0 (mean  $58.4 \pm 4.39$ ) days. The adult individuals reared in the laboratory survived for 65 to 80 (mean  $74.2 \pm 6.87$ ) days.

The efficacy of newer insecticides against pseudostem weevil of banana under laboratory condition revealed that Imidacloprid 0.5 ml/lit. showed 46.19%, 68.22%, 90.88% mortality 24, 48, 72 hrs. after treatment. Whereas, beta-cyfluthrin + imidacloprid 300 OD@1.5 ml/lit showed 30.60%, 37.73%, 86.44% mortality 24, 48, 72 hrs., respectively. The treatment with *B. bassiana* and *M. anisopliae* showed 0.00% mortality 24, 48 and 72 hrs. after treatment, respectively.

The studies carried out on efficacy of newer insecticides against pseudostem weevil of banana under field condition revealed that two applications of the insecticide imidacloprid 17.8 EC@0.5 ml/lit. were found to be superior to all other treatments against pseudostem weevil. Treatment with beta-cyfluthrin + imidacloprid 300 OD@1.5 ml/lit was next in order of efficacy.

The treatment with Imidacloprid showed highest B:C ratio (7.80) followed by treatment with beta-cyfluthrin + imidacloprid (7.32), while regarding ICBR ratio the treatment with *M. anisopliae* showed maximum ratio (174.25) followed by treatment with imidacloprid (115.24) for the pseudostem weevil of banana.

## 1. INTRODUCTION

Banana (*Musa paradisiaca*) is one of the oldest fruits cultivated by man from pre-historic times and today it is the leading tropical fruit in world market with a highly organized and developed industry. India is the largest producer of banana in the world (Sharangi and Acharya, 2007) and West Bengal is a major banana growing state followed by Maharashtra, Tamil Nadu, Gujarat, Karnataka, Andhra Pradesh, Bihar and Madhya Pradesh (Bauri *et al.*, 2014). Banana is the second most important fruit crop of India grown in about 846 thousand hectares with an annual production of 29124 MT, and productivity of 47.6 MT/ hectare (Anonymous, 2015). Banana occupies the first position among the 40 million tonnes of fruits produced in India (Anonymous, 2014).

India is the main producer (about 16%) and Uganda the main consumer (>200kg/ca/yr.) of banana in the world (Arias *et al.*, 2003). The leading producer of Cavendish bananas in the world during 1998 to 2000 was India (19%), followed by Ecuador (12%), China (10%), Colombia (6%) and Costa Rica (5%) (Arias *et al.*, 2003). Latin America contributes 80% of all exported bananas, with the leading countries being Ecuador, Costa Rica and Colombia (Arias *et al.*, 2003). The value of the international banana trade ranges between US about 4.5 and 5 billion dollars per year (Arias *et al.*, 2003). In Maharashtra, 5, 97,000 acres of land is under cultivation of banana with 65.7 MT/ha productivity. Dwarf Cavendish, Basrai, Robusta, Lal Velchi, Safed Velchi, Rajeli Nendran, G-9, Shreemanti, Red banana etc. varieties are cultivated in Maharashtra. Banana fruits is richest source of energy for humans.

Bananas can be used to fighting intestinal disorders like ulcers. Bananas are one of the few fruits that ulcer patients can safely consume. Bananas neutralize the acidity of gastric juices, thereby reducing ulcer irritation by coating the lining of the stomach (Sampath Kumar *et al.*, 2012). In Kolhapur region mostly G-9, Basari, Shreemanti and Deshi varieties are taken (Khairmode *et al.*, 2015). The soil and climate of Kolhapur are ideally suited for banana and, under favourable conditions, the farmers get very high yield from this crop. However, there are a number of limiting factors, which restrict the production and productivity of the crop. One of the major constraints is the high incidence of pests and diseases throughout the year in the state. Though the crop is annual, the perennial nature of its cultivation in the garden lands coupled with the practice of clonal propagation results in the persistence of many economically important pests and diseases. Bananas, a major commodity in the world trade, are susceptible to a variety of serious and debilitating diseases and pests (Simmonds 1959, Royar and Das *et al.*, 1990, Robinson and Eckstein 1996; Viljoen and Robinson, 2002). Insect pests play a major role in lowering both the quantitative and qualitative value of banana.

More than 180 species of insect pests have been recorded on banana world over (Simmonds, 1966), however Ostmark (1974) reported total 470 species of insect pest. In India, 19 species infest banana such as insect pest like Rhizome(corm) weevil (*Cosmopolites sordidus* Germar), Pseudo stem borer (*Odoiporus longicollis* Olivier), Banana aphid (*Pentalonia nigronervosa*), Flea beetles (*Nodostoma sabcostatum*), Fruit / leaf scaring beetle (*N. viridipennis*), Burrowing nematode (*Radopholus similis*), Root-knot nematode (*Meloidogyne incognita*) and (*M. Javanica.*) (Padmanaban and sathiamoorthy, 2002). Among them the pseudostem weevil *Odoiporus longicollis* Olivier (Coleoptera: Curculionidae) is gaining importance as a serious pest causing heavy losses to the grower. A survey was conducted during 2003-2004, in 15 southern districts of Karnataka to know the distribution of the pseudostem weevil, which indicated that the incidence of pseudostem weevil was dominantly observed in Shimoga and Mandya dist.

The banana pseudostem weevil, *Odoiporus longicollis* Olivier has been recorded for the first time in Poonch and Rajouri districts of Jammu region as a major pest of banana plant which are grown in patches in this area (Azam *et al.*, 2010). The pseudostem weevil is believed to have originated in South and South East Asia, which is also the centre of origin of the present day bananas and plantains. This insect is found in India, China, Malaysia, Indonesia and Thailand and is a key pest of bananas and plantains, posing a great threat to banana production systems in these countries (Valmayor *et al.*, 1994). Pest density may vary from field to field. The weevil prefers plantains and highland bananas, particularly 'Pome' types. Total crop failure may result in farms where the weevils are not managed efficiently. Such crop failures are not uncommon in banana production systems in India.

This pest has been reported from all the banana growing states of India viz., Assam, West Bengal, Delhi, Bihar, Uttar Pradesh, Karnataka, Kerala, North East Hill States (Batra, 1952, Shukla and Kumar, 1970, Dutt and Maiti, 1972a, Isahaque, 1978, Jayanthi and Varghese, 1999, Prasad and Singh 1987, Visalakshi *et al.*, 1989). Both larvae and adults caused extensive tunnelling in the leaf sheaths as well as in core region. Percentage incidence ranged between 47-61.2 per cent with a mean of  $54.55 \pm 2.28$  per cent (Singh, 1966). It is estimated that banana pseudostem weevil (*O. longicollis*) has the potentiality to cause 10-90% yield loss depending upon the growth stage of crop as well as management efficiency (Padmanaban and Sathiamoorthy, 2001a).

The present investigation has been conducted which would be helpful in finding out the suitable options to manage this pest. Chemical insecticides invite unwarranted long-term effect, including insecticide resistance (Gold and Messiaen, 2000), pest resurgence, pest

outbreak, ground water contamination and radical effects on beneficial insects (David, 2008), apart from the environmental imbalances due to tottering ecosystem.

In many instances the farmers could diagnose the incidence of the pest only in the later stage of infestation when it may be too late to save the crop. The weevils cause damage to stems and fruit stalks of banana and affect productivity of the crop. Although 8-10 varieties of banana are recommended for cultivation in Maharashtra, expected yield of the crop is not achieved because of the damage caused by weevils to the crop. The management of banana pseudostem weevil, even during the initial stages of infestation, is very difficult mainly because it is an internal feeder. Moreover, the pest may complete the life cycle and start a new generation within the pseudostem (Dutt and Maiti, 1972a). Many of the insecticides previously recommended for the management of the pest like dieldrin (Kung, 1955), endrin, celphos tablets (Dutt and Maiti, 1972b), aldrin, BHC and monocrotophos (Raghunath *et al.*, 1992) were either banned, or being phased out or in restricted use, due to different kinds of toxic hazards. Some of the recommendations of soil treatments and spraying and dusting of pseudostem against the pest appeared to be based on incomplete information on the bionomics and behaviour of the insect (Feakin, 1972 and Rao and Rangaswami, 1972). The biology, bionomics and varietal reaction to infestation of the pest have been studied in other parts of India and in other countries. This information is vital in evolving strategies for the manage of the pest. The studies on biology and management of pseudostem weevil with chemical insecticides form a basis for undertaking the Integrated Pest management. Considering serious of the losses caused by pseudostem weevil on one hand and paucity of the information regarding the chemical control on the other hand. The present investigations were carried out which would be helpful in finding out the suitable options to manage this pest with following objectives:

- 1) To study the seasonal incidence of pseudostem weevil of banana.
- 2) To study the biology of pseudostem weevil of banana.
- 3) To study the efficacy of newer molecule of insecticides against pseudostem weevil of banana under lab condition.
- 4) To study the efficacy of new molecule of insecticide against pseudostem weevil of banana under field condition.



## 2. REVIEW OF LITERATURE

For several years now, banana and plantain yield in the tropical and subtropical regions, where they are the major source of food and revenue, have been adversely affected by infestation of the curculionids, *Odoiporus longicollis* Olivier and *Cosmopolites sordidus* (Ger.) (Sery, 1988). The banana pseudostem weevil, *O. longicollis* is one of the major and serious pests of banana in India for quite a long time (Fletcher, 1914; Batra, 1952; Dutt and Maiti, 1972a). The grub bore in to the pseudostem and break the vascular connections between the roots and the aerial portion of the plant and damage the internal tissues, which results in the breakage of the pseudostem (Luo *et al.*, 1985). Occurrence of this pest in Kerala was reported only in 1989 (Visalakshi *et al.*, 1989). As the published literature on this pest with special reference to Kerala is major, information available on the pest in various banana growing countries are reviewed and presented.

### 2.1 Description of the insect

#### 2.1.1. Adult

The adult weevil is robust, reddish brown to black in colour and measuring 1.3 cm to 2.0 cm in length (Singh, 1966). The adults were less active and weak fliers (Shukla and Kumar, 1966). Dutt and Maiti, (1971) observed black and reddish-brown adult phenae along with intergrading forms of both sexes. Many workers have described the morphology of adults in detail. The body length ranged from 15 to 20 mm excluding the snout. The elytra were hard with longitudinal grooves and did not extend up to the posterior end of the abdomen. The mouthparts were of biting and chewing type and were present at the tip of the snout. The antenna was of elbow type (Shukla and Kumar, 1969). The mean length and width of male and female insects were 15 and 5 mm and 19 and 5.2 mm, respectively. The rostrum in female was significantly larger than that of the male and rostral punctuations were pronounced in males (Jayasree, 1992). Janakiraman (1998) reported that the mean body length and width of male were 15 mm and 3.2 mm respectively and those of female were 16.4 mm and 3.7 mm respectively. The mean rostral lengths of male and female were 3.7 mm and 4.2 mm, respectively.

#### 2.1.2. Egg:

Eggs of the insect were described as smooth, cylindrical with rounded ends, measuring 2 mm in length and 1 mm width diameter (Jayasree, 1992). According to Janakiraman, (1998) the mean length and width of eggs were 2.79 mm and 1.13 mm, respectively. The pre-oviposition period is 15-30 days and the adult weevils mate throughout the day and night. The mean number of eggs laid by a female following a single mating is nine eggs at the rate of one egg per day. Gravid females lay yellowish white, elliptical eggs by inserting the ovipositors through ovipositional slits cut by the rostrum on the outer epidermal layer of the leaf sheath of the

pseudostem down to the air chambers. Oviposition takes place only in the leaf sheaths. The number of eggs deposited is considerably reduced as the number of weevils increases, indicating the existence of a spacing pheromone, epideictic compounds which act as a deterrent to conspecific females (Ranjith and Lalitha, 2001).

### 2.1.3 Grubs

Singh (1966) and Dutt and Maiti (1972a) described the morphology of larvae of the weevil. According to them the grubs are apodous and the colour was usually yellowish white. The mouthparts are of biting and chewing type with strong and dark brown mandibles. They also mentioned that the larvae are soft, fleshy, subcylindrical, wrinkled and covered with sparse brownish setae of different lengths. Jayasree, (1992) reported that the body length and width of first instar larvae were 3.75 and 1.32 mm, second instar larvae 6.25 mm and 1.75 mm, third instar larvae 12.57 mm and 2.78 mm, fourth instar larvae 13.38 mm and 3.38 mm and the fifth instar larvae 18 mm and 4.95 mm, respectively. According to Janakiraman (1998) the mean length was 4.39, 6.65, 10.50, 15.47 and 19.96 mm for I, II, III, IV and V instars and the mean body width was 1.58, 2.32, 3.38, 4.43 and 5.89 mm for I, II, III, IV and V instars, respectively. However, Shukla and Tripathi (2010) reported that larva pass through 5-8 instars.

### . 2.1.4. Pupa

Dutt and Maiti (1972 a) reported that the pupa is exarate, measured 27 to mm in length and 9 to 10 mm in width, pale yellow in colour and formed within a fibrous cocoon. According to Jayasree (1992), the cocoon had a mean length of 32.2 mm and a mean width of 12.73 mm, while the pupa without cocoon measured a mean length of 15.2 mm and a width of 10.34 mm. In Tamil Nadu, the average length and width of pupa were 17.5 mm and 6.6 mm, respectively (Janakiraman, 1998). Pupation is in necked cells near the surface of the host plants (Shukla and Tripathi, 2010).

## 2.2. Distribution

Lefory (1909) reported the occurrence of the pseudostem borer from Andaman Islands as early as 1909. Speyer (1918) recorded miscellaneous pests infesting plantain crop, which included the weevil, *Odoiporus*. Hutson (1921) recorded its occurrence in Sri Lanka and Burma. In Java, almost all varieties of banana were found attacked by the pest (Froggatt, 1928). Hoffmann (1932) reported the weevil from Honkong and Hawaii Islands. In Sri Lanka, *Odoiporus* was reported as a minor pest (Jepson, 1934) and their attack was recorded both in the northwestern and southwestern provinces of the country (Dias, 1935). The weevil was reported from Formosa (Kung, 1955; Wyiniger, 1962) and Kathmandu valley (Singh, 1966), Luo *et al.*, (1985) reported three species of curculionids from China and *O. longicollis* was one among them. This pest has been reported from all the banana growing states of India viz., Assam, West Bengal, Delhi, Bihar, Uttar Pradesh, Karnataka, Kerala, North East Hill States (Batra, 1952,

Shukla and Kumar, 1970, Dutta and Maiti, 1972a, Isahaque, 1978, Jayanthi and Varghese, 1990, Prasad and Singh 1987).

### **2.2.1 Nature of damage:**

Froggatt (1925) reported that *O. longicollis* oviposit in the cut ends of the pseudostem or in an injury from where the emerging larvae could get entry into the centre of the stern. According to him, the emerging larvae fed in and around the bunch stalk and later riddled through the tissues of leaf bases. Hoffmann (1932) stated that the larvae tunnelled within the stern and pupated in cocoons made by fibres of the host plant. The adults and larvae bored through the pseudostem, petioles and fruit stalk causing wilting and finally affecting the flower and bunch emergence (Kung, 1955). Shukla and Kumar (1970) reported that both the larvae and the adults caused damage by tunnelling into the pseudostem and the only outward traces of the damage were the presence of holes of 2 mm in diameter on the pseudostem. Edwards *et al.*, (1973) opined that the damage due to larval tunnelling resulted in stunting and failure to produce fruits and the breaking up of pseudo stern at soil level. Isahaque (1978) observed that all stages of the pest were found in large numbers mostly in the peripheral region of the plants and that the larvae tunnelled the pseudostem and fed voraciously. The larvae went deep into the pseudostem, whereas the adults were found to feed superficially under the leaf sheaths. Visalakshi *et al.*, (1989) found that the grubs of the beetle made extensive tunnels in the pseudostem and as a result the pseudostem rotted and the plants became weak.

Jayasree (1992) observed that the emerging grubs bored into the inner sheaths causing extensive internal riddles and tunnels, that the bore holes exhibited gum exudation in the initial stage of attack and that the badly damaged plants broke at weaker portions of the pseudostem.

### **2.2 Seasonal incidence of Pseudostem weevil of banana:**

Biswas *et al.*, (2015) concluded from the study that during the initial stages of the crop stage, infestation of banana pseudostem weevil was negligible and the pest gradually established with increase in age of the crop as mature plants are preferred by the adults of *O. longicollis*. The trend of incidence pattern showed that pseudostem weevil remains active throughout the year on both the cultivars and population gradually increases during the first ratoon crop or second ratoon crop. However, the degree of damage has been recorded more on cv. Martaman as compared to cv. Kanchkel.

Dutt and Maiti (1970) reported that the plants at 4 to 5 months after planting are more exposed for establishment of pseudostem weevil, it may be due to the fact that initiation and establishment of pseudostem weevil in new field may take more time as compared to old and neglected banana orchards.

Azam *et al.*, (2010) reported that adults breed throughout the year, though activity slows down during December to February. Being internal feeder adult do not undergo hibernation or

winter rest; though, during winter the adults remained confined in the basal decomposed part of the pseudostem and become more active during monsoon period i.e. July to September tunnelling the pseudostem in the upper parts even up to the bunches.

Khairmode *et al.*, (2015) indicated that occurrence of *O. longicollis* on G-9 (hybrid) variety of banana was high in the months of June, September, November, October, April and May and moderate in the months of July, August, November, February and March and low in December and January. Occurrence was noted except the month of November and February which was low and no occurrence on the crop was noted in December and January on Deshi variety of banana in Kolhapur.

### 2.3 Biology of pseudostem weevil of banana

Khairmode *et al.*, (2015) reported that the occurrence of *O. longicollis* on G-9 and deshi varieties was high from the months of June, September, October, April and May. More or less same trend of occurrence was shown by *C. sordidus*. G-9 variety was more susceptible to weevil attack than deshi variety. Under laboratory conditions ( $27 \pm 1^\circ\text{C}$ , 75-80% R.H. and 12 hr photoperiod), life cycle from egg to adult was completed in 32 to 38 days on G-9 variety by *C. sordidus* and *O. longicollis*, respectively. Sexes of both species were polygamous and mated at day and night in *O. longicollis* and at night in *C. sordidus*. The dispersal rate of *O. longicollis* was greater than *C. sordidus*. Azam *et al.*, (2010) reported that the banana pseudostem weevil *Odoiporus longicollis* Olivier larvae and adults caused extensive tunnelling in the leaf sheaths as well as in core region. Percentage incidence ranged between 47- 61.2 per cent with a mean of  $54.55 \pm 2.28$  per cent. Mating occurs in mating spaces between leaf sheath. The pests breed throughout the year and do not undergo winter rest. Black and reddish-brown adults were recorded from the splitted pseudostems of the damaged banana plants and colour difference represents a phenomenon of non sex limited variation in conspecific sympatric phena of the pest.

Gold *et al.*, (2000) stated that weevil attack can prevent crop establishment (Price, 1994), cause significant yield reductions in ratoon crops (Rukazambuga *et al.*, 1998) and contribute to shortened plantation life (Gold *et al.*, 1999).

Kobenan *et al.*, (2015) reported that the larvae by its trophic activities bore into the rhizome, present roots are destroyed and the emergence of new roots is delayed, reducing nutrient uptake and weakening the stability of the plant. Attacks in newly planted banana stands can lead to crop failure. Based on mating studies, it has been concluded that the colour difference is not due to sexual dimorphism but is a phenomenon of non-sex limited variation and of sympatry (Dutt and Maiti, 1972a). The weevils are predominantly nocturnal in habit, although during cloudy days and cooler months they may fly during the daytime. They often confine themselves within the pseudostem and in the decomposing tissues of harvested pseudostems.

Priyadarshini *et al.*, (2014) reported that the incubation period varied from 3 - 4 (mean  $3.6 \pm 0.54$ ) days. The grub passed through five instars to complete the larval period. The total larval period varied from 30 to 35 (Mean  $32.2 \pm 1.92$ ) days. The prepupal period lasted for 3 to 5 (mean  $4.1 \pm 0.89$ ) days. The pupal period lasted for 17 to 20 (mean  $18.6 \pm 1.34$ ) days. The total life cycle of *O. longicollis* from egg to adult emergence varied from 53.0 to 65.0 (mean  $58.4 \pm 4.39$ ) days. The adult individuals reared in the laboratory survived for 65 to 80 (mean  $74.2 \pm 6.87$ ) days. The incidence of pseudostem weevil on banana commenced from February and continued its activity till the month of December 2012 and the maximum number of population (12.76 insects per plant) was recorded during second fortnight of August 2012. The number of holes was observed maximum (14.87 per plant) during second fortnight of August. All the weather parameters except relative humidity at 07 hrs and 14 hrs had significant impact on weevil population and number of holes on pseudostem. All these weather parameters together produced 89.0 and 89.2 per cent impact on weevil population and number of holes produced, respectively.

### **2.3.1 Egg:**

Kung (1955) reported that the eggs were usually laid singly and a female laid up to 11 eggs with an average of six. According to Dutt and Maiti (1972a), eggs were yellowish white in colour and cylindrical in shape with rounded ends and measured about 3.14 mm in length and 1.1 mm in diameter on an average. Incubation period of eggs varied from three to five days in winter. Jayasree (1992) observed that the incubation period ranged from two to three days with a mean of 2.3 days at a mean minimum and maximum temperature of 28°C and 32°C, respectively. In Tamil Nadu, the mean incubation period ranged from three to five days (Janakiraman, 1998).

### **2.3.2. Grub:**

Pinto (1928) reported that the larval period varied from 11 to 18 days under laboratory conditions. Whereas, Kung (1955) observed a longer period of three to six weeks for completing five larval instars. Experiments conducted by Dutt and Maiti (1972 a) indicated that the larval period lasted for 26.2 days in summer and 68.1 days in winter with five larval instars. They observed that the larvae were apodous, soft, fleshy, sub-cylindrical, wrinkled and covered with sparse brownish setae, mandibles two-dentate strong and dark brown, maxillary palpi two segmented, antennae one segmented and the spiracles conspicuous and more or less elliptical in shape. Metathoracic spiracles were found larger than the abdominal spiracles except the 8th abdominal spiracles which were the largest and placed dorsally. Mid-abdominal segments were wider than the thoracic and the caudal segments. Abdominal segments except the 8<sup>th</sup>, 9<sup>th</sup> and 10<sup>th</sup> were provided with three plicae from the dorsal aspect. Pleural folds of each segment were prominent. Pleural folds of each side were with two tubercles, each tubercle bearing a small seta.

The 8th and 9th abdominal tergites were highly chitinised and together formed the anal plate. Anal plate was provided with four setae posteriorly on either side each arising from a small tubercle. The anal plate bent downwards and extended slightly anteriorly on ventral side. The 10th segment was small and inconspicuous, forming lobes around the anal orifice. The lobe bordering the posterior boundary of the anal orifice was the largest and was provided with a setae on either side. Anteriorly, there is a small lobe without any seta while a lobe bearing a seta bounded each orifice. Jayasree (1992) reported that there were five distinct larval instars which lasted for two to three, four to seven, four to six, five to seven and six to eight days, respectively at a mean temperature range of 26 to 32°C. Janakiraman (1998) reported that the larval period ranged from 25 to 43.5 days and the mean larval period was 31.33 days. There were five instars totally and the duration of each instar was 2.7, 4.25, 4.5, 6.43 and 13.9 days.

### **2.3.3 Pupa:**

Kung (1955) reported a pre-pupal period of three to seven days and a pupal period of three to thirteen days. He also observed that the adults remained in the cocoon for seven to fourteen days.

Dutt and Maiti (1972a) reported that the pupal period including pre-emergence resting period of adults lasted for 20 to 24 days in summer and 37 to 44 days in winter. They also reported that the pupa was exarate, pale yellow in colour and the head and base of the rostrum were with few prominent setae. A pair of setae near the mid and tip region of the rostrum reached the first coxae ventrally. Prothoracic shield had two pairs of heavily chitinised dome like structures anteriorly. Antenna was as geniculate, short, rectangular at the anterior end of the mesothorax ventrally. In Kerala, the pupal period including the pre emergence resting period lasted for ten to thirteen days with an average of 11.2 days (Jayasree, 1992). In Tamil Nadu, the pupal period lasted for 19 to 22 days including the pre emergence resting period of three to four days (Janakiraman, 1998).

### **2.3.4 Adult:**

The adult longevity ranged from 145 to 235 days with an average of 170 days and under starved conditions, the adults survived for 1 to 2 weeks (Jayasree, 1992).

## **2.4 Sexual dimorphism:**

Singh (1966) observed that the males were black in colour and smaller in size whereas, the females were reddish brown in colour and bigger in size. However, Shukla and Kumar (1969) could observe black female weevils, which were smaller in size and reddish-brown males, which were bigger in size.

## **2.5 Efficacy of New Molecule of Insecticides Against Pseudostem Weevil Under Lab Condition:**

Akello *et al.*, (2008) reported that *Beauveria bassiana* and *Trichoderma spp.* these fungi have shown high levels of internal colonization of banana tissues with good potential for managing the banana weevil.

Bortoluzzi *et al.*, (2013) evaluated isolated entomopathogenic nematodes under laboratory conditions and also their interaction with a chemical insecticide (carbofuran), aiming at their use for the weevil borer control. Sixteen *Sterinernematidae* and *Heterorhabditidae* isolates were evaluated and applied over the banana tree pseudo stem (100 JIs/cm<sup>2</sup>) and they were compared to one another concerning mortality caused in adult's individual of *C. sordidus*. The insecticide did not affect the viability of the isolate, but it really harmed its infectivity, although it did not affect the development of the symbiotic bacterium.

Shukla and Tripathi (2010) found that *M. anisopliae* an entomopathogenic fungus affected more than 90 per cent mortality under laboratory conditions.

Irulandi *et al.*, (2012) found that monocrotophos (4ml/plant) when applied by injection into the stem caused more per cent mortality of the weevil i.e. 84.61 and 96.15 per cent at 72 and 96 hrs of the treatment, respectively. This treatment was followed by azadirachtin 10000ppm (1:4, pseudostem injection) and *B. bassiana* (applied on the pseudostem trap) recorded 84.74 and 75.36 per cent mortality of weevil after 96 hrs of treatment, respectively.

Sivasubramanian *et al.*, (2009) opined that the stem injection of Neem Azal (4:4, stem injection) recorded high per cent mortality of the pseudostem weevil in banana and this is in close agreement with the present investigation.

## **3.1 Efficacy of New Molecule of Insecticides Against Pseudostem Weevil Under Field Condition.**

Chemical control of the beetle has been employed since the early 20<sup>th</sup> century. Pesticides consisted mainly of Paris Green, followed by the use of organochlorines like BHC and DDT (Froggatt 1925, Cuillé 1950, Simmonds 1966; Treverrow *et al.*, 1992). The chemicals were usually applied with flour or other substances as baits (Froggatt,1925, Cuillé,1950, Simmonds,1966; Treverrow *et al.*,1992). This method was not very effective (Simmonds, 1966) and the persistent cycloidiens, dieldrin and aldrin, showed high efficacy as a soil treatment against the banana weevil (Braithwaite, 1958). Cycloidiens was used extensively around the world from the mid 1950's (Edge, 1974) and was found to be effective for up to years after application (Braithwaite, 1967). Before 1970, resistance to cycloidiens was widely diagnosed (Vilardebo, 1967, Anonymous 1969; Shanahan and Goodyer, 1974). Investigations into

alternative chemicals (mainly organophosphates and carbamates) showed chlordecone (organochlorine), pirimiphos-ethyl, chlorpyrifos.

Gold *et al.*, (2003) recorded that systemic chemicals (dimethoate, omethoate, aldicarb, carbofuran, carbosulfan, fenamiphos, fosthiazate, isazofos, monocrotophos, oxamyl, phorate and terbufos) can potentially control larvae following uptake by banana roots after soil application.

Treverrow *et al.*, (1992) reported that these chemicals provide a protective treatment for plants but have relatively shorter residual actions and do not prevent attacks on plant residues after harvest. Dual action insecticide-nematicides with systemic action will be of value to treat moderate weevil infestations when nematode densities also require treatment.

Sathiamoorthy, (1998) reported that the stem injection of monocrotophos is extensively used in controlling *O. longicollis*.

Sivsubramanian *et al.*, (2009) reported that stem injection of neemazal @ 4:4 ratio recorded the highest per cent reduction (85.48) of pseudo stem borer infestation over control than the rest of the concentrations (1:4, 2:4, and 3:4). Swabbing of neemazal (4%) reduced the infestation of borer by 42.84 per cent than the untreated plants. However, application of neemazal by stem injection was proved to be more effective than by swabbing. Stem injection of neemazal (4:4) recorded 93.81 per cent mortality of pseudo stem weevil after 96 hours of application while swabbing of neemazal (4%) recorded only 43.74 per cent mortality.

Stem injection of neemazal (4:4) recorded the lowest per cent damage of 1.10, 0.75 and 1.07 per cent on outer, middle and inner sheaths, respectively. Swabbing of neemazal (4%) recorded 1.59, 0.74 and 0.28 per cent damage on outer, middle and inner sheaths, respectively.

Alter and Vandenberg (2000) reported that the mycoinsecticide based on *B. bassiana*, *Paecilomyces fumosoroseus* have been used to control various insect pests.

Padmanaban and Sathiamoorthy (2001a) stated that natural enemies including arthropods, entomopathogenic nematodes and Musa germplasm for resistance to weevils has the potential programmes.

Justin *et al.*, (2008) reported that the disc-on stump and longitudinal split pseudostem traps can be efficiently used to monitor and reduce the weevil population. Pseudostem injection of monocrotophos or dimethoate:water (1:5) can be recommended for the effective management of this pest.

Irulandi *et al.*, (2012) reported that stem injection of monocrotophos, azadirachtin and the application of *B. bassiana* recorded the highest per cent mortality of 96.15, 84.74 and 75.36%, respectively, after 96 hrs of application. All the treatments were found to increase the fruit yield with better cost benefit ratio

Reddy *et al.*, (2015) reported that infestation caused by the weevils varied in different genotypes and also this information may be further helpful in selecting the resistant germplasms for future.

### 3. MATERIALS AND METHODS

The details of the material used and methods adopted in the present investigations are described in this chapter.

#### 3.1 Location of the experiments

Field experiment was conducted during Kharif season of 2017 on the Farmers field located at Mangaon, Taluka- Chandgad, Dist- Kolhapur (Maharashtra), which is situated on 16° 16' North latitude and 73° 58' East longitude with an altitude of 511 meters above mean sea level.

##### 3.1.1 Climatic conditions

The mean annual rainfall of Kolhapur is about 1050- 1100 mm, receiving mostly during June to October. The rainfall is assured for kharif season. Summer is dry, while winter is cool. The maximum temperature varies from 25.4 °C in December to 35 °C in May. The minimum temperature varies from 11.32 °C and 25.77 °C in winter and summer, respectively. The mean relative humidity ranges from 50 to 90 per cent. The climate is subtropical. The meteorological data of year 2016-17, is used for obtaining correlation coefficients.

##### 3.1.2 Soil type

The field selected for experiment was uniform with sandy loam soil having medium fertility and fairly good drainage. To understand the biology of *O. longicollis*, investigations were carried out in the Department of Entomology, College of Agriculture, Kolhapur, Maharashtra during the period 2016-2017. The objectives of the study were to understand the biology of the pseudostem weevil, *O. longicollis* infesting banana in Maharashtra and to evolve an integrated strategy for its management. The field experiment was conducted on the farmer field in Kolhapur district.

G-9 (Hybrid) and deshi varieties of banana planted in four blocks have been selected for studying biology of weevil, *O. longicollis*. Occurrence, life cycle, mating, oviposition and damage by weevils on *Musa spp.* G-9 and deshi varieties have been studied by spot observations at weekly interval during the years 2016-2017. Life cycle was studied with respect to eggs laid and incubation, number of instars and pupae and their duration for development. Adult longevity, mating and oviposition and damage caused by weevils were studied by spot observations in the field. The life cycle was also studied in the laboratory at 27±1°C and 75-80% R.H.

#### 3.2 Seasonal incidence of Pseudostem weevil of banana

With a view to determine fluctuations in the seasonal incidence of pseudostem weevil in Kolhapur region, a fixed plot survey was conducted at Research Farm. To study the incidence pattern, the experiment was laid out at locations in Kolhapur district during March 2017 to Nov, 2017 on G-9 variety. The planting of banana has been completed within Nov, 2016. For this

purpose, ten infested banana plants about five months old crop were randomly selected. The crop was grown by adopting all the recommended agronomic practices uniformly, keeping them completely free from insecticidal contamination. The observation on pest activity was initiated to monitor the pest population from March 2017 to November 2017. The data so obtained were merged together to calculate mean fortnight population. The number was recorded by counting the total number of holes on pseudostem plants including those hidden inside the pseudostem during morning hours before 9 AM. The data, so obtained, were finally used to work out the mean number of insects per plant. Similarly, total number of holes made by insects were also counted on the pseudostem. Data on mean number of live and dead holes were correlated with meteorological parameters recorded simultaneously. The small black pin head spots on the pseudostem have been counted visually for incidence studies (Priyadarshini *et al.*, 2014). The small black pin head spots on the pseudostem have been counted visually for incidence studies. The per cent incidence of the pest has been calculated using the following formula

$$\text{Per cent incidence} = \frac{\text{Number of live holes}}{\text{Total number holes}} \times 100$$

For correlation studies, weekly observations of five meteorological parameters viz. maximum and minimum temperature, morning and evening relative humidity (RH) and number of rainy days have been recorded and tested for their overall influence on biological activities of pseudostem weevil.

### 3.3 To Study the Biology of Pseudostem Weevil of Banana

#### 3.3.1 Materials required-

Rearing cages, pseudostem of banana, Grubs of the weevil, glass troughs, muslin cloth, fine camel hair brush, petri dishes, filter paper, hand lens, water,

The biology of *O. longicollis* was studied in the laboratory of Department of Entomology. Rearing of *O. longicollis* was done on pseudostem of banana kept in rearing cages (24" × 12" × 12"). The pseudostem was cut into pieces of 10 cm length. Five small holes were made in the cut surface. Grubs of the weevil collected from the field were introduced at the rate of one per hole. The pieces of pseudostem were changed once in two days and the larvae were taken out and introduced into fresh ones. This was continued till pupation. After pupation, the cocoons were collected and kept in glass troughs covered with wet muslin cloth for adult emergence. Newly emerged adults were collected. Male and female adults were separated based on their rostral characters (Jayasree, 1992). Five pairs of weevils were isolated from the cage immediately after adult emergence from the cocoons. They were kept in pairs separately in small rearing cages. Pieces of healthy pseudostem of banana were provided in the cages for feeding.

The eggs laid in the air chambers of the sheath were collected from the cages and the eggs deposited in the sheath were isolated with fine camel hair brush and counted separately. The pseudostem pieces were replaced with fresh ones every day. Eggs were examined every day for the hatching of grub. The freshly laid eggs were taken out from the pseudostem and were kept on filter paper in three covered petri dishes with sufficient moisture. To maintain sufficient moisture inside, a few drops of water were taken on the filter paper. At the time of hatching the hand lens was used to see the changes occurring on the eggs. To assess the larval behaviour and the duration of different larval instars of banana pseudostem weevil, the newly hatched larvae were collected and transferred carefully using a wet camel hair brush into fresh pseudostem pieces of 10 cm in length in to the test tube.

The pseudostem pieces were changed once in two days till pupation of the grubs. While transferring into fresh pseudostem pieces, the larvae were examined for signs of moulting. The interval between two moults was taken as length of each instar. Constant humidity of 70-80 per cent R.H. level was maintained by utilizing water soaked cotton balls. The rearing provided an opportunity to observe the behaviour and development of the larvae and to assess the number of grub instars. The fifth instar larvae enter a non-feeding pre-pupal stage and constructs a cocoon by winding short pieces of fibrous materials of the sheath around its body (Padmanaban and Sathiamoorthy, 2001b). The date and time of cocoon formations were recorded as soon as they were formed. After pupation, the cocoons were collected along with pieces of pseudostem and kept in petri dishes for adult emergence and the pupal period was recorded. As soon as the adult weevils emerged from the cocoons, they were separated in pairs and reared in rearing cages on pieces of banana leaf sheath. The longevity of both male and female weevils along with prevailing temperatures was noted. The rearing cages and culture rooms were disinfected regularly with formalin to avoid contamination. Rearing cages were kept away from ants.

### **3.4 To Study Efficacy of Newer Insecticides Under Lab Condition**

#### **3.4.1. Materials required:**

*M. anisopliae* and *B. bassiana* was available in Entomology Section, College of Agriculture, Kolhapur and chemical insecticides purchased from local market. Petri plates, forceps, and pseudostems of banana.

**Table.1 Treatment Details-****Treatments under lab condition-**

Sr. No.	Treatment No.	Treatments	Dose
1	T1	Triazophos 40 EC	4.28ml
2	T2	Imidacloprid 17.8 EC	0.5ml
3	T3	Neemazal	10000ppm
4	T4	Cyantraniliprole 10.26 OD	0.5ml
5	T5	Beta- cyfluthrin +Imidacloprid 300 OD	1.5ml
6	T6	<i>Beauveria bassiana</i>	8gm
7	T7	Chlorpyriphos 20 EC	2.5ml
8	T8	<i>Metarhizium anisopliae</i>	8gm
9	T9	Control	

**3.4.2 Stem dip method:**

The suspension of insecticides individually and in given combinations were prepared according to the required quantity as per recommended dose. The laboratory bioassay studies were under taken in complete randomized block design (CRBD). All the above treatments were evaluated for their efficacy against banana pseudostem weevil in the laboratory. The control was maintained separately. Five 3<sup>rd</sup> instar grubs were released in the respective treatments and their mortality was noted after 24, 48 and 72 hrs. and the per cent mortality was calculated for each treatment day for the emergence of larva and the experiment was repeated thrice.

**3.4.3 Observations:**

The grub mortality was recorded after the treatment at an interval of 24, 48, and 72 hours after treatment. The exact time required to kill the test larva was strictly recorded.

**3.4.4 Statistical analysis**

The data on percentage were transformed into corresponding *angle/arc-sin* percentage. The data gathered from laboratory experiments were subjected to statistical scrutiny following the methods of Gomez and Gomez (1985).

**Table. 2 Details of Insecticides Used Against Pseudostem weevil of Banana**

Sr. No	Technical name	Chemical name	Trade name	Formulation	Company Name
T1	Triazophos 40 EC	O, O-Diethyl O-(1-phenyl-1H-1,2,4-triazol-3-yl) phosphorothioate	Trizostar	EC	Excel crop care
T2	Imidacloprid 17.8 EC	1-(6-chloro-3-pyridin-3-ylmethyl)-N-nitroimidazolidin-2-ylideneamine (IUPAC)	Confidor	EC	Byre Crop Science
T3	Neemazal	Neem seed product	Neem raj	SC	Neem raj
T4	Cyantraniliprole 10.26 OD	3-Bromo-N-[4-chloro-2methyl]-6-[(methylamino) carbonyl] phenyl]-1-(3-chloro-2-pyridinal)-1H-pyrazole-5-carboxamide	Benevia	OD	Dupont
T5	Beta-cyfluthrin +Imidacloprid 300 OD	(2E)-1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine + cyano(4-fluoro-3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2dimethyl cyclopropanecarboxylate	Solomon	OD	Byre
T6	<i>Beauveria bassiana</i>	Fungus	Phule <i>Beauveria</i>	WP	MPKV, Rahuri
T7	Chlorpyrifos 20 EC	O, O-Diethyl O-3,5,6-trichloropyridin-2-yl phosphorothioate	Tricel	EC	Cheminova, Inc
T8	<i>Metarhizium anisopliae</i>	Fungus	Phule <i>Metarhizium</i>	WP	MPKV, Rahuri

### **3.5 To Study efficacy of newer insecticides Against Pseudostem weevil of Banana under field condition.**

Study of efficacy of newer insecticides against pseudostem weevil of banana under field condition was conducted during 2016-17.

#### **3.5.1 Experimental details.**

The details of the experiment are as under:

Design	: RBD
Replications	: Three
Treatments	: Nine
Plot size	: Gross: 21 m x 21 m : Net: 20 m x 20 m
Spacing	: 1.5 m x 1.5 m
Crop	: Banana
Variety	: G-9
Date of planting	: 10/11/2016
Date of 1 <sup>st</sup> spraying	: 18/08/2017
Date of 2 <sup>nd</sup> spraying	: 29/09/2017
Date of harvesting	: 02/11/2017

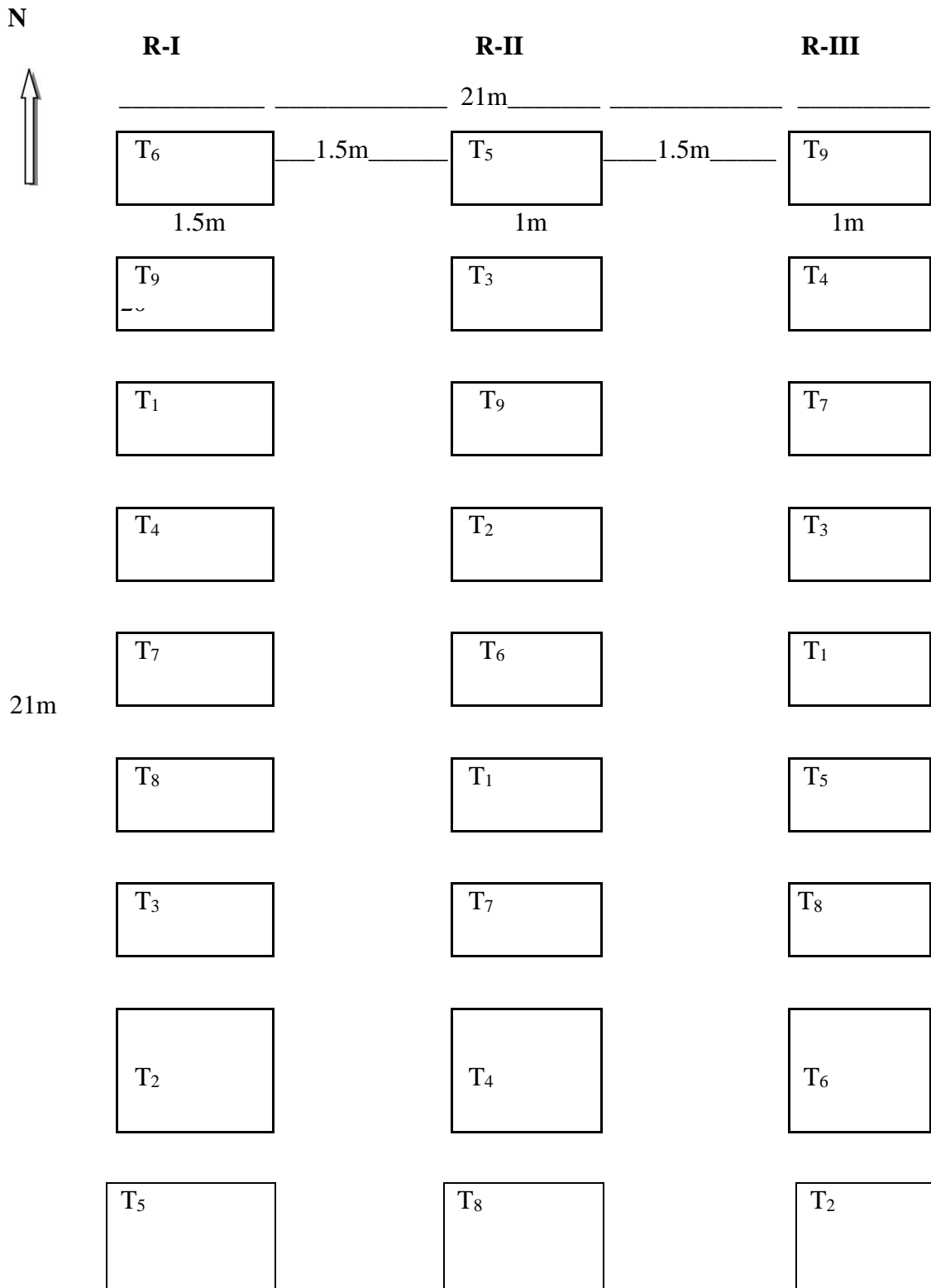


Fig. 1 Plan of layout

### 3.5.3 Details of Experiment:

In the present experiment nine insecticidal treatments including control were maintained and particulars of evaluated pesticides *viz.*, common name, chemical name, trade name, formulation and source and are presented in Table 2 and Table 3, respectively.

### 3.5.4 Materials required:

Hand injector, Syringes, *M. anisopliae* from Entomology Section, College of Agriculture, Kolhapur and chemical insecticides were purchased from local market.

Field trial was conducted at the farmers field located at Mangaon, Taluka- Chandgad, Dist.-Kolhapur (Maharashtra) to evaluate the efficacy of newer insecticides for the management of pseudo stem weevil. All the agronomic practices were adopted uniformly for all the treatments. The field experiment was laid out on 8 month old banana plants in 1 ha area in Randomized Block Design with altogether nine treatments which were replicated thrice and the application of insecticide treatments were undertaken using the stem injector. Solution 10ml /plant was injected into the stem at 45 and 150 cm height from the ground level through banana pseudostem injector. The symptoms *viz.*, presence of small pin head holes on the stem, fibrous extrusions from bases of leaf petioles and exudation of gummy substance from the holes on the pseudostem caused by stem weevil were observed at 10 days intervals. The observations were recorded 10 days after each treatment. Pre-treatment counts on the number of bore holes /plant was done before a day of treatment.

**Table. 3 Treatment Details under Field condition-**

Sr. No.	Treatment No.	Treatments	Dose
1	T1	Triazophos 40 EC	4.28ml
2	T2	Imidacloprid 17.8 EC	0.5ml
3	T3	Neemazal	10000ppm
4	T4	Cyantraniliprole 10.26 OD	0.5ml
5	T5	Beta- cyfluthrin+ Imidacloprid 300 OD	1.5ml
6	T6	<i>Beauveria bassiana</i>	8gm
7	T7	Chlorpyriphos 20 EC	2.5ml
8	T8	<i>Metarhizium anisopliae</i>	8gm
9	T9	Control	

**3.6.3 Statistical analysis-**

The data on percentage were transformed into corresponding *angle/arc-sin* percentage. The data gathered from field experiments were subjected to statistical scrutiny following the methods of Gomez and Gomez (1985).

## 4. RESULTS AND DISCUSSION

Investigations were made on the seasonal incidence, biology of pseudostem weevil of banana and also efficacy of newer insecticides *viz.* triazophos 40 EC, imidacloprid 17.8 EC, cyantraniliprole 10.26 OD, beta-cyfluthrin+ imidacloprid 300 OD, chlorpyrifos 20 EC, neemazal, *B. bassiana*, and *M. anisopliae* against pseudostem weevil of banana under lab and field condition during season 2016-2017 to 2017-18, respectively.

The field experiments were conducted to study these aspects and the results obtained are presented and discussed in this chapter in the light of earlier studies.

### 4.1 Seasonal Incidence of Pseudostem Weevil of Banana:

The data presented in the Table 4 and depicted in Fig. 2 clearly indicated that the initial infestation of 0.50 per cent first appeared in the 11<sup>th</sup> MW corresponding to last week of March, 2017 when the average minimum and maximum temperature varied from 18 °C to 24 °C and 1.40 per cent infestation in the 12<sup>th</sup> MW corresponding to second week of April when the average minimum and maximum temperature varied from 18 °C to 25 °C and average minimum and maximum relative humidity ranged from 78% to 82 %, respectively with 00 mm rainfall. Then, infestation gradually increased up to September, 2017 and declined gradually during winter. Subsequently, infestation reached its first peak in 34<sup>th</sup> MW corresponding to 37<sup>th</sup> week of September, 2017 (20%) per cent when the average minimum and maximum temperature varied from 17.5 °C to 30.7 °C and average minimum and maximum relative humidity ranged from 75 % to 81 %, respectively with 2.45 mm rainfall. This reveals that the infestation was positively correlated with maximum temperature ( $r = 0.55$ ), rainfall ( $r=0.53$ ) and negatively correlated with minimum temperature (0.13), relative humidity (0.40). The per cent (85% and 90%) damage was more during monsoon period i.e. August to September during 2017, respectively which is more or less similar with the findings of Dutt and Maiti (1972a).

Similar results were also reported by Azam *et al.*, (2010). They indicated that as soon as the temperature rises its activity start rising and thus with the onset of rain during monsoon period i.e. July to September, its infestation reached maximum.

Nair *et al.*, (2004) also reported that during rainy season (June- August), the incidence attained its peak in different parts of Kerala.

It can be concluded that *O. longicollis* is active throughout the year. Population is found to be low during the winter months. Initial infestation starts from February 2010 onwards. With the increase in temperature as well as with onset of monsoon, the peak incidence was achieved during September. The damage showed a positive correlation with weather parameters.

**Table 4: Seasonal incidence of pseudostem weevil of banana during 2016-17.**

Meteorological Week (MW)	Per cent infested plant	Temperature (°C)		Relative Humidity (%)		Average Humidity	Rainfall (mm)
		Max	Min	Morning	Evening		
8 (March)	0.00	23.2	17.2	89	75	82	0.00
9	0.00	24.0	18.4	90	75	82.5	0.00
10	0.00	24.5	17.8	88	78	83	0.00
11	0.50	24.9	18.2	88	69	78.5	0.00
12 (April)	0.80	25.0	18.5	89	71	80	0.00
13	1.50	25.8	19.0	92	80	86	0.00
14	1.80	26.7	19.3	88	69	78.5	0.00
15	2.00	27.2	18.8	89	87	88	0.00
16	3.02	28.1	19.1	90	81	85.5	0.00
17(May)	3.20	28.5	18.0	83	80	81.5	0.00
18	3.50	28.3	18.1	85	63	74	0.00
19	3.80	26.0	18.7	86	77	81.5	0.00
20	4.10	29.1	19.1	83	59	71	01.5
21(June)	4.60	28.5	17.5	82	69	75.5	02.7
22	4.75	30.7	17.8	82	60	71	29.9
23	4.00	23.2	17.2	89	75	82	175.2
24	4.50	24.0	18.4	90	75	82.5	178.5
25(July)	5.20	24.5	17.8	88	78	83	170.6
26	6.0	24.9	18.2	88	69	78.5	168.3
27	6.30	25.0	18.5	89	71	80	166.7
28	6.90	25.8	19.0	92	80	86	100.4
29	7.00	26.7	19.3	88	69	78.5	27.1
30(August)	9.50	27.2	18.8	89	87	88	1.1

Continue...

Meteorological Week (MW)	Per cent infested plant	Temperature (°C)		Relative Humidity (%)		Average Humidity	Rainfall (mm)
		Max	Min	Morning	Evening		
31	10.12	28.1	19.1	90	81	85.5	01.1
32	12.30	28.5	18.0	83	80	81.5	01.9
33	14.00	28.3	18.1	85	63	74	17.9
34(Sept)	15.00	26.0	18.7	86	77	81.5	44.0
35	17.50	29.1	19.1	83	59	71	1.5
36	18.30	28.5	17.5	82	69	75.5	2.7
37	20.00	28.5	17.5	82	69	75.5	2.7
38	20.10	30.7	17.8	82	60	71	2.9
39(Oct)	15.10	31.9	17.2	81	49	65	0.00
40	14.00	31.7	14.9	76	41	58.5	0.00
41	12.30	31.8	14.2	70	58	64	0.00
42	11.50	31.9	17.2	81	49	65	0.00
43(Nov)	9.50	31.7	14.9	76	41	58.5	0.00
44	8.50	31.8	14.2	70	58	64	0.00
45	7.20	31.2	10.6	68	48	58	0.00
46	7.10	30.8	12.3	73	57	65	0.00
47	7.00	30.4	9.5	76	51	63.5	0.00

The infestation was noticed up to end of November. Infestation also observed after harvesting of banana if these plants were not removed from the field considered as source of infestation to the next season.

**Table 5. Correlation of Pseudostem weevil incidence with weather parameters:**

Sr. No.	Meteorological Parameters				
	Pest	Max. Temp.	Min Temp.	Relative Humidity	Rainfall
	Correlation coefficient ('r') values				
1)	<b>Pseudostem Weevil</b>	<b>0.55*</b>	<b>-0.13*</b>	<b>-0.40</b>	<b>0.53</b>

**(\*) = 5 per cent significant**

## 4.2 Biology of Pseudostem Weevil (*O. longicollis*) of Banana:

The Banana pseudostem weevil breeds throughout the year but Thippaiah *et al.*, (2011) noticed its activity slow down during December-February in a study from Bangalore, Karnataka.

### Mating and oviposition:

Mating was observed from the ninth day after emergence of adults from cocoons during day and night and they mated more than once. During mating the female weevil carried the male on its back. Mating period lasted for 3 to 4 minutes. Mating happen either outside the pseudostem or in the space between the outermost and inner sheaths of the pseudostem which is similar to findings of Dutt and Maiti, (1972a). The weevil is characteristic in negative phototropism, gregariousness, hydrotropism and death mimicry (Kung, 1955). In contrast to Gailce *et al.*, (2008) found that they are poor fliers and crawl swiftly on the surface of the ground. Zhou and Wu (1986) opined that adults are active during night and full-grown larvae overwinter in old banana stems. Adults show cannibalistic nature when they are kept along with the grubs, despite the availability of their natural food (Tripathi and Chaturvedi, 1978).

Reproductive behaviour of the pseudostem weevil was studied by Dutt and Maiti (1972a), Azam *et al.*, (2010), Thippaiah *et al.*, (2011) and Irulandi *et al.*, (2012). Adults mate frequently throughout the day and night, but prominently at daytime. By feeding adults engrave mating spaces between the leaf sheaths (Azam *et al.*, 2010). Dutt and Maiti (1972a) reported mating at any time outside the pseudostem or in the space between the outermost and inner sheaths of the pseudostem.

### Egg:

The female laid eggs by inserting their ovipositor through the ovipositional slits (Plate No.4). The female weevils cut oviposition slits with the rostrum on the outer epidermal layer of pseudostem. Under laboratory conditions, a cluster of 4-5 eggs was laid at the cut end of the pseudostem within the air chamber by the adult female weevil, the leaf sheath down to the air chambers. One egg was laid in one air chamber. Eggs were yellowish white in colour and cylindrical in shape with rounded ends. Initially the egg was compact and later a prominent area of air space was found at one end. Freshly laid eggs were translucent, yellowish in colour and more or less cylindrical in shape with rounded ends, with somewhat prominent area of air space at the anterior end. The incubation period was studied by taking these eggs from the pseudostem and was kept on filter paper in 5 covered petri dishes with sufficient moisture. The incubation period varied from 3 - 4 (mean  $3.6 \pm 0.54$ ) days.

This finding is in partial agreement with the result of Thippaiah *et al.*, (2012) who reported that the mean incubation period varied between 3-5 days during June to August and between 5-8 days during December to February. The present finding is also in conformity with the results of Padmanaban and Sathimoorthy (2001b).

**Grubs:**

The grubs were apodus, soft, fleshy and covered with brownish setae of different lengths. In early instars, the grubs were creamy white and later yellowish in colour. Mandibles were strong and dark brown in colour. The grubs started feeding one to two hours after the emergence from eggs. Newly emerged grubs showed a tendency to feed on other eggs in the vicinity. The first instar grubs were found to feed on the soft parenchymatous tissues of the air chambers. As they grew, they fed on the epidermal layer of the leaf sheaths.

**Larval period:**

The number of larval instars was found to be five. Freshly emerged larva was yellowish white, apodus, soft, wrinkled, bulged in the middle and pointed towards both ends.

**First instar:**

The first instar lasted for 3 to 4 (Mean  $3.3 \pm 0.44$ ) days. Head was yellowish brown with anterior margin of cranium reddish brown. The body appeared whitish in colour. The body length and width varied significantly. The body length ranged from 2.90 mm to 3.75 mm. (Plate No.4)

**Second instar:**

The second instar occupied 3 to 5 (Mean  $4.2 \pm 0.83$ ) days (Plate No.4). The second instar grubs showed significant variation in length and width 6.22 mm and 2.22 mm, respectively.

**Third instar:**

The third instar grub lasted for 5 to 6 (Mean  $5.6 \pm 0.5$ ) days. The body length recorded in the third instar grub 9.22 mm and width 2.23 mm. The width of third instar grubs also showed significant variation when reared in laboratory. The width of grubs ranged from 2.15 mm to 3.05 mm (Plate No.4)

**Fourth instar:**

The fourth instar grub increased in size and occupied 6 to 7 (Mean  $6.9 \pm 0.45$ ) days. The mean length and width is 11.68 mm and 3.32 mm (Plate No.5).

The third, fourth and fifth instar are voracious feeders and riddle the pseudostem by cutting sometimes holes on the outer surface for better aeration of the tunnels, thereby cause heavy damage to the plantations (Azam, *et al.*, 2010).

**Fifth instar:**

Fifth instar was yellowish white, stout, fleshy and head free, reddish brown in colour and rounded abdominal tip. Mandibles stout, more or less triangular with bluntly pointed three apical denticles. This instar occupied 12 to 13 (Mean  $12.4 \pm 0.54$ ) days. The total larval period varied from 30 to 35 (Mean  $32.2 \pm 1.92$ ) days. The mean length and width is 16.50 mm and 4.20 mm (Plate No.5)

Padmanaban *et al.*, (2001) documented that the total larval period varied from 30.5 to 35 (Mean  $33.1 \pm 1.85$ ) days during June-August and, between 51 to 62 (Mean  $58.7 \pm 3.71$ ) days during December-February.

Thippaiah *et al.*, (2012) observed that there were five larval instars having mean 2.80, 4.10, 5.40, 6.90 and 13.10 days for I, II, III, IV and V instars, respectively which is more or less similar to the present findings. Similar observations have been reported by various other workers (Ocampo and Medina, 2006; Bhagawati *et al.*, 2009).

#### **Pre - Pupal and Pupal period:**

The fifth instar larvae before entering into prepupal stage makes the cocoon by winding short pieces of fibrous materials of the leaf sheath around its body. The cocoon was dark brown in colour, elongate and cylindrical in shape. The pre - pupal period lasted for 3 to 5 (mean  $4.1 \pm 0.89$ ) days.

#### **Pupa:**

The fully-grown fifth instar grub constructed a cocoon and pupation took place within a fibrous cocoon (Plate No.5). Cocoons were constructed at the end of the larval tunnel towards the outer sheath of the pseudo stem as showed in Plate No.5. It was formed along the long axis of the pseudostem. One end of the cocoon was kept open by the grub. The grub in prepupal stage remain inside the cocoon for one to two days. Just before pupation, they cut short pieces of fibre from the epidermal layer of the leaf sheath within reach of its head. This process made a rectangular hole on the outer sheath of the pseudo stem. Externally, the presence of a cocoon could be diagnosed by the presence of a rectangular hole on the pseudo stem. The pupa was of exarate type and pale yellow in colour with a few prominent setae on the head and base of the rostrum and a tuft of hairs on the anal region. The pupal period lasted for 17 to 20 (mean  $18.6 \pm 1.34$ ) days. Similar type of work has been documented by several workers (Ocampo and Medina, 2006; Myat, 2010; Azam *et al.*, 2010 and Thippaiah *et al.*, 2012).

#### **4. Total life cycle:**

The total life cycle of *O. longicollis* from egg to adult emergence varied from 53.0 to 65.0 (Mean  $58.4 \pm 4.39$ ) days. The present result is in close conformity with the report of Thippaiah *et al.*, (2012) who documented that the total life cycle of *O. longicollis* from egg to adult emergence varied from 53.0 to 66.0 (mean  $59.90 \pm 5.20$ ) days during June- August and 80 -100 days with an average of (mean  $90.9 \pm 6.72$ ) days during December- February.

#### **5. Adult stage:**

Adult weevils had a pre-emergence resting period of two to three days. At the time of emergence, they were brown in colour and later turned to black. In some cases, reddish brown adults were also noticed. Adult weevils preferred shady and humid conditions. They remained inside the pseudo stem during daytime. The emerging adults started feeding on the same day

itself. Head of the weevil was round with an anterior rostrum. Eyes situated towards the base of the rostrum. Mouthparts were biting and chewing type. Antennae were reddish brown in colour. Legs were of equal length. Third tarsal segment was expanded and leaf shaped. Distal abdominal segments were found extending beyond the elytra. Adult weevils exhibited sexual dimorphism. The rostral surface was rough in males whereas it was smooth in females. Adults were robust, reddish brown and black in colour. Some adults mostly remained inside the pseudostem and fed on the dead plant tissue. The reddish brown and bigger weevils were females, whereas the black and smaller weevils were males. The colour difference is due to sexual dimorphism. The adult individuals reared in the laboratory survived for 50 to 60 (Mean 55) days.

Thippaiah *et al.*, (2012) reported that the adult individuals reared in the laboratory survived for 52 to 60 days with an average of (Mean  $56.2 \pm 3.0$ ) days during June - August and 75 to 90 (Mean  $81 \pm 5.42$ ) days during December- February. These present results are more or less in agreement with the findings of Shukla and Kumar (1969); Dutt and Maiti (1972a); Visalakshi *et al.*, (1989); Lalitha *et al.*, (2000); Padmanaban *et al.*, (2002); Ocampo and Medina (2006); Justin *et al.*, (2008) and Azam *et al.*, (2010).

**Table 6. Duration of different life stages of *O. longicollis* (N =50).**

Instar	Larval duration (days)	
	Range	Mean $\pm$ SD
I	3-4	$3.3 \pm 0.44$
II	3-4	$3.3 \pm 0.83$
III	5-6	$5.6 \pm 0.5$
IV	6-7	$6.9 \pm 0.45$
V	12-13	$12.5 \pm 0.54$

**Table 7. Duration of Life cycle *O. longicollis*.**

<b>Life stages</b>	<b>Range (days)</b>	<b>Mean <math>\pm</math> SD</b>
Incubation period	3-4	3.6 $\pm$ 0.54
Larval period	30-35	32.2 $\pm$ 1.92
Pre-pupal period	4-5	4.1 $\pm$ 0.89
Pupal period	18-21	18.6 $\pm$ 1.34
Total development period	12-14	58.4 $\pm$ 4.39
Adult longevity	55-65	60 $\pm$ 6.87

**Nature of damage:**

The adults caused damage to the plants by making oviposition punctures on the outer sheath of the plant and feeding on the pseudo stem. Grubs were found to be more injurious than the adult weevils. The adult females deposited the eggs in air chambers. From air chambers of the outer leaf sheath the developing grubs tunnelled towards the central core of the pseudo stem. They feed on the central portion (aerial stem) of the pseudo stem by tunnelling towards the base as well as towards the top portion (Plate No.6). The tunnelling sometimes reached up to the midrib of the leaves and peduncle of the bunches. When the grubs were in the later fifth instar stage, they moved towards the outer sheath of the pseudo stem. Then they constructed cocoons along the long axis of the pseudostem.

**4.3 Efficacy of Newer Insecticides Against Pseudostem Weevil of Banana Under Lab Condition:**

Eight different insecticides including formulations of *M. anisopliae*, *B. bassiana* individually and in combinations were tested for determining their combine efficacy against grubs of *O. longicollis*. The dead grubs were observed on first, second and third day interval after the treatment.

**4.3.1 Efficacy of Newer Insecticides Against Pseudostem Weevil of Banana At 1 DAT:**

The mortality of the grubs ranged from 29.99 to 46.19 per cent when the observations were taken at 1 DAT. The treatment with Imidacloprid 17.8 EC @ 0.5 ml per liter recorded highest 46.19 per cent mortality and found to be significantly superior over all other treatments. The treatment with cyantraniliprole 10.26 OD @ 0.5 ml per liter was next in order of efficacy recorded 35.99 per cent mortality. Whereas, *B. bassiana* and *M. anisopliae* recorded 0.00 per cent mortality which is lowest mortality and equal to untreated control.

#### 4.3.2 Efficacy of Newer Insecticides Against Pseudostem Weevil of Banana At 2 DAT:

At 2 DAT the treatment with Imidacloprid @ 0.5ml per litre was found to be significantly superior over all other treatments and recorded 68.22 per cent mortality as compared to 0.00 per cent mortality in untreated control. The treatment with triazophos 40 EC was next in order of efficacy where 60.00 per cent mortality was recorded. The treatment with cyantraniliprole 10.26 OD, chlorpyrifos 20 EC and neemazal found to be equally effective where 53.32, 43.33 and 34.44 per cent mortality of the grubs, respectively was recorded under laboratory condition. Treatment of *M. anisopliae* and *B. bassiana* showed 20.79 and 4.17 per cent mortality, respectively.

#### 4.3.3 Efficacy of Newer Insecticides Against Pseudostem Weevil of Banana At 3 DAT

The treatment with Imidacloprid @ 0.5 ml per litre was found to be constantly superior over all other treatments and recorded 90.88 per cent mortality as against 00.00 per cent mortality in untreated control. The treatment with beta-cyfluthrin + imidacloprid 300 OD was next in order of efficacy where 86.44 per cent mortality was recorded. The treatment with cyantraniliprole 10.26 OD and triazophos 40 EC were found to be equally effective in causing the grub mortality 84.44 and 81.33, respectively. Treatment of *M. anisopliae* and *B. bassiana* showed 37.50 and 27.70 per cent mortality. (Plate No.7)

The overall performance of the treatment with imidacloprid 17.8 EC was most effective recording 46.19, 68.22 and 90.88 per cent per cent grub mortality when the observations were recorded at 1, 2 and 3 DAT and it was found to be significantly superior over all other treatments. The least per cent grub mortality was recorded in untreated control when observations were recorded at 1, 2 and 3 DAT, respectively. The treatment with beta-cyfluthrin + imidacloprid 300 OD were next in order of efficacy causing mortality 86.44 per cent of grub at 1, 2 and 3 DAT followed by cyantraniliprole 10.26 OD causing mortality 84.44 per cent.

This is in close agreement with the investigations of Irulandi *et al.*, (2012) who reported that among treatments tested in laboratory, monocrotophos (4ml/plant) when applied by injection into the stem caused more per cent mortality of the weevil i.e. 84.61 and 96.15 per cent at 72 and 96 hrs. of the treatment, respectively. This treatment was followed by azadirachtin 10000ppm (1:4, pseudostem injection) and *B. bassiana* (applied on the pseudostem trap) was 84.74 and 75.36 per cent mortality of weevil after 96 hrs. of treatment, respectively. Sivasubramanian *et al.*, (2009) opined that the stem injection of neemazal (4:4, stem injection) recorded high per cent mortality of the pseudostem weevil in banana and this is in close agreement with the present investigation.

**Table 8. Efficacy of Newer insecticides against grubs of *O. longicollis***

Tr. No.	Treatment	Dose/lit g/ml	Mean Per cent Mortality		
			1 DAT	2 DAT	3 DAT
T1	<b>Triazophos 40 EC</b>	4.28	30.22 (33.35)	60.00 (50.77)	81.33 (64.40)
T2	<b>Imidacloprid 17.8 EC</b>	0.5	46.19 (42.81)	68.22 (55.69)	90.88 (72.72)
T3	<b>Neemazal</b>	10	29.57 (32.94)	34.44 (35.93)	73.33 (58.91)
T4	<b>Cyantraniliprole 10.26 OD</b>	0.5	35.99 (36.84)	53.32 (46.90)	84.44 (66.77)
T5	<b>Beta-cyfluthrin+ imidacloprid 300 OD</b>	1.5	30.60 (33.58)	37.73 (37.90)	86.44 (68.39)
T6	<i>Beuveria bassiana</i>	20	0.00 (0.00)	4.17 (11.78)	27.70 (31.74)
T7	<b>Chlorpyriphos 20 EC</b>	2.5	29.99 (33.20)	43.55 (41.29)	81.30 (64.38)
T8	<i>Metarhizium anisopliae</i>	20	0.00 (0.00)	20.79 (27.13)	37.50 (37.76)
T9	<b>Untreated control</b>		0.00	00	0.00
	<b>SE±</b>	<b>NS</b>	<b>1.42</b>	<b>1.67</b>	<b>2.10</b>
	<b>CD at 5%</b>	<b>NS</b>	<b>4.27</b>	<b>5.02</b>	<b>6.30</b>
	<b>CV</b>		<b>8.14</b>	<b>7.53</b>	<b>6.29</b>

DAT= Days after Treatment

\*Figures in parentheses are arc-sin transformed values.

#### **4.4 Efficacy of Newer Insecticides Under Field Condition (1<sup>st</sup> Application)**

Response of eight different insecticides including formulations of *M. anisopliae*, *B. bassiana* individually and in combinations were tested for determining their combine efficacy against grubs of *O. longicollis*. The dead holes were observed at 10<sup>th</sup>, 20<sup>th</sup>, 30<sup>th</sup> and day interval after the treatment.

##### **4.4.1 Efficacy of Newer Insecticides Under Field Condition At 10 DAT:**

The treatment with triazophos 40 EC @ 4.28 ml/lit. recorded highest dead hole per cent 44.07 and found to be significantly superior over all other treatments. The treatment with Imidacloprid @0.5 ml per liter was next in order showing dead holes per cent 43.14. Whereas, *B. bassiana* and *M. anisopliae* recorded 23 and 25.36 per cent which is lowest dead holes recorded.

##### **4.4.2 Efficacy of Newer Insecticides Under Field Condition 20 DAT:**

The treatment with imidacloprid 17.8 EC @ 0.5 ml per liter recorded highest dead hole per cent 68.25 and found to be significantly superior over all other treatments. The treatment with triazophos @ 4.28 ml per liter was next in order showing dead holes per cent 63.94. Whereas, *B. bassiana* and *M. anisopliae* recorded 48.52 and 40.80 per cent which is lowest dead holes recorded.

##### **4.4.3 Efficacy of Newer Insecticides Under Field Condition at 30 DAT:**

The treatment with imidacloprid 17.8 EC @0.5 ml per liter recorded highest dead hole per cent 88.59 and found to be significantly superior over all other treatments. The treatment with beta-cyfluthrin + imidacloprid @ 1.5 ml per liter was next in order showing dead holes per cent 78.75. Whereas, *B. bassiana* and *M. anisopliae* recorded 63.53 and 56.34per cent which is lowest dead holes recorded.

**Table 9. Efficacy of Newer Insecticides against Pseudostem weevil of Banana under Field condition (1<sup>st</sup> Application)**

Tr. No.	Treatments	Mean Precount	Mean dead holes 10 DAT	Per cent reduction	Mean dead holes 20 DAT	Per cent reduction	Mean dead holes 30 DAT	Per cent reduction	Mean percentage
T <sub>1</sub>	<b>Trizophos 40 EC</b>	7.26 (3.19)	3.20 (1.92)	44.07 (41.59)	4.57 (2.25)	62.94 (52.42)	5.07 (2.35)	69.83 (56.60)	58.94 (50.10)
T <sub>2</sub>	<b>Imidacloprid 17.8 EC</b>	11.26 (3.85)	4.80 (2.30)	42.62 (41.06)	6.00 (2.54)	53.28 (55.70)	9.33 (3.13)	82.85 (63.38)	59.58 (53.86)
T <sub>3</sub>	<b>Neemazal</b>	8.00 (3.32)	2.50 (1.92)	31.25 (33.99)	5.47 (2.44)	68.37 (51.38)	6.00 (2.54)	75.00 (60.00)	58.20 (49.60)
T <sub>4</sub>	<b>Cyantraniliprole 10.26 OD</b>	9.60 (3.59)	3.50 (2.16)	36.45 (43.21)	5.87 (2.52)	61.14 (53.09)	7.57 (2.84)	78.75 (62.55)	58.81 (49.94)
T <sub>5</sub>	<b>Beta-cyfluthrin +imidacloprid 300 OD</b>	11.40 (3.87)	3.90 (2.12)	34.21 (35.80)	5.43 (2.43)	47.63 (43.49)	8.90 (3.06)	78.07 (62.80)	53.30 (46.89)
T <sub>6</sub>	<i>Beuveria bassiana</i>	9.13 (3.52)	2.10 (1.61)	23.00 (28.66)	4.43 (2.22)	48.52 (44.15)	5.83 (2.51)	63.85 (53.04)	45.12 (42.20)
T <sub>7</sub>	<b>Chlorpyriphos 20 EC</b>	9.53 (3.58)	3.20 (1.92)	33.57 (36.30)	5.43 (2.43)	56.97 (49.01)	5.97 (2.54)	62.64 (52.26)	51.06 (45.27)
T <sub>8</sub>	<i>Metarhizium anisopliae</i>	9.46 (3.57)	2.40 (1.74)	25.36 (30.40)	3.87 (2.08)	40.90 (39.76)	5.33 (2.41)	56.34 (48.64)	40.86 (39.72)
T <sub>9</sub>	<b>Untreated control</b>	10.46 (3.78)	00 (0.71)	00	00 (0.71)	00	00 (0.71)	00	00
	<b>SE±</b>	<b>NS</b>	<b>0.061</b>		<b>0.044</b>		<b>0.085</b>		
	<b>CD at 5%</b>	<b>NS</b>	<b>0.18</b>		<b>0.13</b>		<b>0.25</b>		
	<b>CV</b>		<b>5.88</b>		<b>3.51</b>		<b>6.11</b>		

DAT= Days after Treatment

\*Figures in parentheses are arc sine and  $\sqrt{X + 0.5}$  transformed values.

## **4.5 Efficacy of Newer Insecticides Under Field Condition (2<sup>nd</sup> Application)**

### **4.5.1 Efficacy of Newer Insecticides Under Field Condition At 10 DAT:**

The treatment with triazophos 40 EC @ 4.28 ml per liter recorded highest dead hole 61.35 per cent and found to be significantly superior over all other treatments. The treatment with imidacloprid @ 0.5 ml per liter was next in order showing dead holes 56.70 per cent. Whereas, *B. bassiana* and *M. anisopliae* recorded 42.63 and 36.60 per cent which is lowest dead holes recorded.

### **4.5.2 Efficacy of Newer Insecticides Under Field Condition At 20 DAT:**

The treatment with imidacloprid 17.8 EC @ 0.5 ml per liter recorded highest dead hole per cent 83.50 and found to be significantly superior over all other treatments. The treatment with *M. anisopliae* @ 8gm per liter was next in order showing dead holes per cent 82.16. Whereas, cyantraniliprole 10.26 OD @ 0.5ml and beta-cyfluthrin 300 OD recorded 65.49 and 67.36 per cent which is lowest dead holes recorded.

### **4.5.3 Efficacy of Newer Insecticides Under Field Condition At 30 DAT**

The treatment with imidacloprid 17.8 EC @ 0.5 ml per liter recorded highest dead hole per cent 95.87 and found to be significantly superior over all other treatments. The treatment with beta-cyfluthrin + imidacloprid @ 1.5 ml per liter was next in order showing dead holes per cent 95.05 per cent. Whereas, *B. bassiana* and *M. anisopliae* recorded 84.21 and 88.00 per cent which is lowest dead holes recorded.

Overall performance of the treatment with imidacloprid @ 0.5 ml/lit was found significantly superior to all the treatment followed by treatment with triazophos 40 EC, chlorpyrifos 20 EC, and neem azal 10 ml.

Imidacloprid was highly effective chemical against *O. longicollis*, minimizing damage to the periphery, cortex and central cylinder of the rhizome and significantly reduced adult density. The percentage reduction in these important damage parameters after chemical application should be considered as conservative measures. The data showed an increase of up to 11.29% in effective bunch weight in the imidacloprid treatments. The results suggested that fipronil and imidacloprid, both considered to be systemic chemicals (Potter 1998; Nel *et al.*, 2002), provided a protective treatment when the injected residue is physically attached to the mother plant. The high efficacy achieved after injection of imidacloprid into plant, residues provides an optimal chemical strategy in an integrated pest management programme for the banana weevil. This finding gain support from the report of Chemical control of *Cosmopolites sordidus* in South Africa, University of Pretoria.

Ogenga-latigo and Masanzam (1996) reported the use of insecticides viz., chlorpyrifos, Pirimiphos, and carbofuran controlled the banana pseudostem weevil more effectively than the fungal pathogen, *B. bassiana*.

Sivasubramanian *et al.*, (2009) stated that the stem injection of neemazal in water (4:4 ratio) was found to be effective in the management of pseudostem weevil in banana.

However, not much work in literature is available on effect of imidacloprid on pseudostem weevil of banana under lab and field conditions to compare our research findings.

**Table 10. Efficacy of Newer Insecticides Against Pseudostem weevil of Banana under Field condition (2<sup>nd</sup> Application)**

Tr. No.	Treatments	Mean Precount	Mean dead holes 10 DAT	Per cent reduction	Mean dead holes 20 DAT	Per cent reduction	Mean dead holes 30 DAT	Per cent reduction	Mean percentage
T <sub>1</sub>	<b>Triazophos 40 EC</b>	5.20 (2.78)	3.20 (1.94)	61.53 (51.56)	3.72 (1.17)	71.53 (64.41)	4.80 (2.69)	92.30 (73.89)	75.12 (62.26)
T <sub>2</sub>	<b>Imidacloprid 17.8 EC</b>	9.70 (3.61)	5.50 (2.44)	56.70 (48.85)	8.10 (2.93)	83.50 (66.03)	9.30 (2.93)	95.87 (78.27)	78.69 (62.57)
T <sub>3</sub>	<b>Neemazal</b>	6.80 (3.10)	3.20 (1.90)	47.05 (43.28)	5.40 (2.42)	79.41 (63.01)	6.00 (2.42)	88.23 (69.94)	71.54 (57.76)
T <sub>4</sub>	<b>Cyantraniliprole 10.26 OD</b>	8.50 (3.41)	4.83 (2.29)	56.82 (48.92)	5.60 (2.46)	65.49 (54.02)	7.56 (2.46)	88.94 (70.58)	70.41 (57.05)
T <sub>5</sub>	<b>Beta-cyfluthrin+ imidacloprid 300 OD</b>	9.50 (3.58)	4.90 (2.71)	51.57 (45.90)	5.40 (2.42)	67.36 (55.16)	9.03 (2.42)	95.05 (77.14)	71.32 (57.620)
T <sub>6</sub>	<i>Beuveria bassiana</i>	5.70 (2.88)	2.43 (1.71)	42.63 (40.76)	4.47 (2.22)	70.00 (56.79)	4.80 (2.22)	84.21 (66.59)	65.61 (54.10)
T <sub>7</sub>	<b>Chlorpyriphos 20 EC</b>	6.80 (3.10)	3.20 (1.97)	47.05 (43.31)	5.37 (2.42)	78.82 (62.60)	6.20 (2.42)	91.71 (73.27)	72.52 (58.38)
T <sub>8</sub>	<i>Metarhizium anisopliae</i>	6.00 (2.94)	2.20 (1.67)	36.60 (37.23)	4.93 (2.33)	82.16 (65.02)	5.30 (2.33)	88.00 (69.73)	68.92 (56.12)
T <sub>9</sub>	<b>Untreated control</b>	12.40 (4.20)	0.00 (0.71)	00	0.00 (0.71)	00	0.00 (0.71)	00	00
	<b>SE<sub>±</sub></b>	<b>NS</b>	<b>0.13</b>		<b>0.048</b>		<b>0.085</b>		
	<b>CD at 5%</b>	<b>NS</b>	<b>0.41</b>		<b>0.14</b>		<b>0.25</b>		
	<b>CV</b>		<b>12.50</b>		<b>3.64</b>		<b>6.11</b>		

DAT= Days after Treatment,

\*Figures in parentheses are arc sine and  $\sqrt{X + 0.5}$  transformed values

**Table 11. Cost Benefit Ratio of Chemical Applications against Pseudostem Weevil of Banana**

Tr. No.	Treatment	Yield of Banana Ton /ha	Additional Yield over control Ton /ha	Additional income over control Rs/ha	Cost of Cultivation except cost of treatment Rs/ha	Cost of Treatments Rs/ha	Total cost of cultivation on Rs/ha	Gross monetary Return Rs/ha	Net return Rs/ha	B:C Ratio	ICBR
T1	<b>Triazophos 40 EC</b>	74	9	76500	90000	968	90968	629000	538032	6.96	79.02
T2	<b>Imidacloprid 17.8 EC</b>	80	15	12700	90000	110	90110	680000	589890	7.80	115.24
T3	<b>Neemazal</b>	73	8	68000	90000	1890	91890	620500	528610	6.85	35.97
T4	<b>Cyantraniliprole 10.26 OD</b>	75	10	85000	90000	2288	92288	637500	545212	7.02	37.15
T5	<b>Beta-cyfluthrin+ imidacloprid 300 OD</b>	78	18	15300	90000	1150	91150	663000	571850	7.32	13.30
T6	<i>Beuveria bassiana</i>	69	4	34000	90000	1080	91080	586500	495420	6.47	31.48
T7	<b>Chlorpyriphos 20 EC</b>	74	9	78500	90000	440	90440	629000	538560	6.97	174.25
T8	<i>Metarhizium anisopliae</i>	68	3	25500	90000	1080	91080	578000	486920	6.38	23.61
T9	<b>Untreated control</b>	65	-	-	-	-	-	-	-	-	-

Cost of Banana-Rs.8500/tons

#### **4.6 Cost Benefit Ratio for Pseudostem Weevil of Banana:**

The data in Table.11 revealed that maximum net returns were recorded with treatment with imidacloprid (80 tons/ha) followed by the treatment with beta-cyfluthrin+ imidacloprid (78 tons/ha) and treatment with Cyantraniliprole 10.26 OD (75 tons/ha) as compared to check plot (65 tons/ha). The highest cost benefit ratio was observed in treatment with imidacloprid (7.80) followed by the treatment with beta-cyfluthrin+ imidacloprid (7.32). However, the highest incremental cost benefit ratio was observed in treatment with Chlorpyriphos 20 EC (174.25). This may be due to the less cost of insecticides. It was followed by the treatment with Imidacloprid 17.8 EC (115.24). But as per Banana growers point of view, net returns per hectare were received with treatment with imidacloprid (Rs. 58,9890/-) which was followed by treatment beta-cyfluthrin+ imidacloprid (Rs. 57,1850/-). Hence, it can be concluded that the application of imidacloprid 17.8 EC and beta-cyfluthrin+ imidacloprid 300 OD can be recommended to control pseudostem weevil of banana.

## 5. SUMMARY AND CONCLUSION

### 5.1 Summary:

Investigations were undertaken with a view to study the seasonal incidence of pseudostem weevil of banana, biology of pseudostem weevil of banana, efficacy of newer insecticides against pseudostem weevil of banana under lab condition and efficacy of newer insecticides against pseudostem weevil of banana under field condition. The results obtained are summarized here under.

### 5.2 Seasonal Incidence of Pseudostem Weevil of Banana:

Initial infestation started from 0.50 per cent during 11<sup>th</sup> MW corresponding to 3<sup>rd</sup> week of March when the average minimum and maximum temperature varied from 17 °C to 24 °C and average minimum and maximum relative humidity ranged from 78% to 82 %, respectively with 00 mm rainfall. Then, infestation gradually increased up to September corresponding to 34<sup>th</sup> MW and declined gradually during winter. Subsequently, infestation reached its first peak in September, 2017 (20%) when the average minimum and maximum temperature varied from 17.5 °C to 30.7 °C and average minimum and maximum relative humidity ranged from 75 % to 81 %, respectively with 2.45 mm rainfall. On the other hand, the least infestation 0.50 was observed during March 2017. During this period the average minimum and maximum temperature were 18 and 24°C and average minimum and maximum relative humidity ranged from 75% to 82 % reveals that the infestation was positively correlated with maximum temperature ( $r= 0.55$ ), rainfall ( $r=0.53$ ).and negatively correlated with minimum temperature (0.13), relative humidity (0.40) and The per cent (85% and 90%) damage was more during monsoon period i.e. August to September during 2017, respectively.

### 5.3 Biology of Pseudostem Weevil (*O. longicollis*) of Banana:

The female laid eggs by inserting their ovipositor through the ovipositional slits. Under laboratory condition a cluster of 4-5 eggs were laid at the cut end of the pseudostem within the air chamber by the adult female. Eggs were yellowish white in colour and cylindrical in shape with rounded ends. Grubs were apodus, soft, fleshy and covered with brownish setae of different lengths. In early instars, the grubs were creamy white and later yellowish in colour. The number of larval instars was found to be five. Freshly emerged larva was yellowish white, apodus, soft, wrinkled, bulged in the middle and pointed towards both ends. The fifth instar larvae before entering into pre-pupal stage makes the cocoon by winding short pieces of fibrous materials of the leaf sheath around its body. The cocoon was dark brown in colour, elongate and cylindrical in shape. The prepupal period lasted for 3 to 5 (mean  $4.1 \pm 0.89$ ) days. The fully-grown fifth instar grub constructed a cocoon and pupation took place within a fibrous cocoon. Cocoons were

constructed at the end of the larval tunnel towards the outer sheath of the pseudo stem. Incubation period was 3-4 days, Larval period was 30-35 days, Pre-pupal period was 4-5 days, Pupal period was 18-21 days, Total development period was 12-14 days.

#### **5.4 Efficacy of Newer Insecticides Against Pseudostem Weevil of Banana, *Odoiporus longicollis* (Olivier) Under Lab Condition:**

Overall performance of various insecticidal treatments based on the mean indicated that the treatments with Imidacloprid at the dose of 0.5 ml per litre was found to be superior over all other treatments and recorded 68.43 per cent mortality. The treatment with cyantraniliprole 10.26 OD, triazophos 40 EC and chlorpyrifos recorded mean per cent mortality of 57.88, 57.18 and 51.61, respectively.

#### **5.5 Efficacy of Newer Insecticides Against Pseudostem Weevil of Banana, *Odoiporus longicollis* (Olivier) Under Field Condition:**

Overall performance of various insecticidal treatments based on the mean per cent reduction indicated that the treatment with Imidacloprid at the dose of 0.5 ml per litre was found to be superior over all other treatments and recorded 65.22 per cent reduction. Treatment with triazophos 40 EC @ 4.28 ml was next in order recorded 58.85 per cent reduction in first application.

Treatment with Imidacloprid 17.8 EC @ 0.5ml/litre recorded highest dead hole 95.87 and treatment with beta cyfluthrin+ imidacloprid was next in order recorded 95.05 per cent reduction. however, it was on par with the treatment with Imidacloprid 17.8 EC. The treatment with triazophos @ 4.28 ml per litre was next in order showing 92.30 per cent reduction in live holes. Whereas, *B. bassiana* and *M. anisopliae* recorded 84.21 and 88 per cent which is lowest dead holes recorded.

#### **5.6 Effect on Banana Yield:**

The results obtained from the data on average yield of marketable banana as influenced by various treatments revealed that all the treatments were significantly superior over untreated control. The treatment with imidacloprid 17.8 EC was emerged as most promising superior treatment giving 80 tons /ha yield followed by the treatment Beta-cyfluthrin+ imidacloprid 300 OD (78 tons/ha). The next promising treatments were Cyantraniliprole 10.26 OD and triazophos 40 EC, Chlorpyrifos 20 EC recording 75 ,74 and 74 tons /ha. However, lowest yield 68 tons/ha was obtained from the treatment with *M. anisopliae* treated plot as against 65 tons/ha in untreated control.

## 5.7 Conclusion:

It can be concluded that the infestation was positively correlated with maximum temperature ( $r= 0.55$ ), and negatively correlated with minimum temperature (0.13), relative humidity (0.40) and rainfall (0.53). The per cent (85% and 90%) damage was more during monsoon period i.e. August to September during 2017, respectively

The incubation period varied from 3 - 4 (mean  $3.6 \pm 0.54$ ) days. The grub passed through five instars to complete the larval period. The total larval period varied from 30 to 35 (Mean  $32.2 \pm 1.92$ ) days. The prepupal period lasted for 3 to 5 (mean  $4.1 \pm 0.89$ ) days. The pupal period lasted for 17 to 20 (mean  $18.6 \pm 1.34$ ) days. The total life cycle of *O. longicollis* from egg to adult emergence varied from 53.0 to 65.0 (mean  $58.4 \pm 4.39$ ) days. The adult individuals reared in the laboratory survived for 65 to 80 (mean  $74.2 \pm 6.87$ ) days.

The studies carried out on efficacy of newer insecticides against pseudostem weevil of banana under field condition revealed that two applications of the insecticide Imidacloprid 17.8 EC 0.5 ml/lit. were found to be superior all over the treatment against pseudostem weevil. Treatment with beta-cyfluthrin + imidacloprid 300 OD 1.5 ml/lit were next in order of efficacy.

The treatment Imidacloprid showed highest B:C ratio (7.80) followed by treatment beta-cyfluthrin + imidacloprid (7.32), while regarding ICBR ratio, the treatment with chlorpyrifos 20 EC showed maximum ratio (174.25) followed by treatment with Imidacloprid (115.24) for the pseudostem weevil of Banana.

Higher returns per hectare were received with application of imidacloprid (Rs. 58,9890/-) which was followed by treatment with beta-cyfluthrin+ imidacloprid (Rs. 57,1850/-). Hence, it can be concluded that the application of Imidacloprid 17.8 EC and beta-cyfluthrin+ imidacloprid 300 OD are most effective insecticides for the control of pseudostem weevil of banana.

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# VITAE

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**MASTER OF SCIENCE (AGRICULTURE)**  
**IN**  
**AGRICULTURAL ENTOMOLOGY**

**2018**

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