BIOLOGY OF BANANA PSEUDOSTEM WEEVIL

Odoiporus longicollis Oliv.

(COLEOPTERA : CURCULIONIDAE)

By

JAYASREE, T. V.

THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur
Kerala

1992

DECLARATION

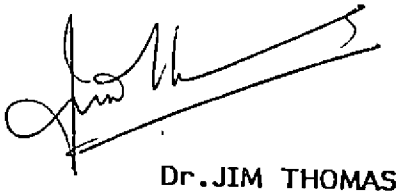
I hereby declare that this thesis entitled "Biology of Banana Pseudostem Weevil, Odoiporus longicollis Oliv. (Coleoptera:Curculionidae)" is a bonafide record of research work done by me during the course of research and this thesis has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
9-7-1992.

JAYASREE, T.V.

CERTIFICATE

Certified that this thesis entitled, "Biology of Banana Pseudostem Weevil, Odoiporus longicollis Oliv. (Celeoptera:Curculionidae)" is a record of research work done independently by Ms.Jayasree, T.V. under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, fellowship, or associateship to her.



Dr.JIM THOMAS
Chairman
Advisory Committee
Associate Professor
Department of Entomology

Vellanikkara,
9.7.1992.

ACKNOWLEDGEMENT

I wish to acknowledge the expert guidance, constant encouragement and patience of Dr.Jim Thomas, Associate Professor, Department of Entomology, College of Horticulture and Chairman of my advisory committee who gave generous long hours of his time in discussing the problems pertaining to this study. Without his co-operation understanding and help, this task would not have been accomplished. I am grateful to him for his constant encouragement and cordial treatment which he has bestowed upon me during the course of my research work and the preparation of this thesis.

I am also grateful to Dr.T.S.Venkitesan, Professor and Head, Department of Agricultural Entomology; Dr.D.Sitarama Rao, Associate Professor, Department of Agricultural Entomology and Sri.P.C.Jose, Professor and Head, Department of Plant Pathology, College of Horticulture, Vellanikkara for their constructive criticism and valuable suggestions as the members of my Advisory Committee.

I am deeply obliged to Sri.D.Joseph, Professor of Entomology, now at Rice Research Station, Moncompu; Dr.K.J.Joseph, Rtd. Professor of Zoology, Calicut University; Sri.V.K.Raju, Assoc. Professor, Department of Processing Technology and Sri.S.Krishnan, Assistant Professor, Department of Agricultural Statistics, College of Horticulture, Vellanikkara for their sincere advice, help, valuable suggestions rendered during the preparation of the thesis.

I am also indebted to all the members of staff in the Department of Entomology, for their valuable help and guidance at each stage of my work.

My sincere thanks are also due to Dr.T.Sreekumaran and Dr.D.Jayaprakash, Associate Professors, College of Veterinary and

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.Jayasree, T.V.**, a candidate for the degree of Master of Science in Agriculture majoring in Agricultural Entomology, agree that the thesis entitled, "Biology of Banana Pseudostem Weevil Odoiporus longicollis Oliv. (Coleoptera:Curculionidae)" may be submitted by Ms.Jayasree, T.V. in partial fulfilment of the requirements for the degree.

Chairman:

Dr.Jim Thomas
Associate Professor
Dept. of Agrl. Entomology
College of Horticulture
Vellanikkara

Members:

Dr.T.S.Venkitesan
Professor and Head
Dept. of Agrl. Entomology
College of Horticulture
Vellanikkara

Dr.D.Sita Rama Rao
Associate Professor
Dept. of Agrl. Entomology
College of Horticulture
Vellanikkara

Dr.A.Sukumara Varma
Associate Professor
Dept. of Plant Pathology
College of Horticulture
Vellanikkara

29-8-92
V. A. Abraham
Sr. Scientist
CPCRI, Kayamkulam
External Examiner

ACKNOWLEDGEMENT

I wish to acknowledge the expert guidance, constant encouragement and patience of Dr.Jim Thomas, Associate Professor, Department of Entomology, College of Horticulture and Chairman of my advisory committee who gave generous long hours of his time in discussing the problems pertaining to this study. Without his co-operation understanding and help, this task would not have been accomplished. I am grateful to him for his constant encouragement and cordial treatment which he has bestowed upon me during the course of my research work and the preparation of this thesis.

I am also grateful to Dr.T.S.Venkitesan, Professor and Head, Department of Agricultural Entomology; Dr.D.Sitarama Rao, Associate Professor, Department of Agricultural Entomology and Sri.P.C.Jose, Professor and Head, Department of Plant Pathology, College of Horticulture, Vellanikkara for their constructive criticism and valuable suggestions as the members of my Advisory Committee.

I am deeply obliged to Sri.D.Joseph, Professor of Entomology, now at Rice Research Station, Moncompu; Dr.K.J.Joseph, Rtd. Professor of Zoology, Calicut University; Sri.V.K.Raju, Assoc. Professor, Department of Processing Technology and Sri.S.Krishnan, Assistant Professor, Department of Agricultural Statistics, College of Horticulture, Vellanikkara for their sincere advice, help, valuable suggestions rendered during the preparation of the thesis.

I am also indebted to all the members of staff in the Department of Entomology, for their valuable help and guidance at each stage of my work.

My sincere thanks are also due to Dr.T.Sreekumaran and Dr.D.Jayaprakash, Associate Professors, College of Veterinary and

Animal Sciences, Mannuthy for enabling me to utilize the Electron Scanning Microscopy and photographic fascilities in their laboratory. Sri.Kumaran, Artist, Department of Extension, College of Veterinary and Animal Sciences has prepared the scientific drawings and sketches in the thesis, for which, I record my deep appreciation.

I am also extremely thankful and obliged to all my friends, especially Sri.Kurien Raphel; Ms.Prameela,P; Mrs.Jyothi Bhaskar and Mrs.Savithri, A. for all their constant selfless, benevolent help extended to me during the study.

My heartfelt thanks are due to Smt.Rukiya in assisting me in the maintenance of the weevil culture for the study and also due to Sri.Joy for neatly typing the manuscript in the thesis form.

It is with deep sense of gratitude that, I remember the love, encouragement and co-operation of my parents and my brother without which I would not have completed the above work.

Above all, I bow my head to the Almighty God who blessed me with health and confidence to undertake this venture successfully.

JAYASREE, T.V.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

The pseudostem weevil, Odoiporus longicollis Oliv. (Coleoptera: Curculionidae) is considered as one of the economic pests infesting the banana crop in the North-eastern parts of the Indian sub-continent and elsewhere in some other countries like Sri Lanka (Speyer, 1918), Java (Frogatt, 1928), Hongkong and Hawai Islands (Hoffmann, 1932), Formosa (Kung, 1954) and China (Luo et al., 1985). Very recently the same pest was reported to be causing severe damage to the common cultivars of banana in a few pockets of the Ernakulam district viz., Perumbavoor, Kalady, Vazhachal, Vengola and Alwaye regions. Of late, it is found to be threatening the banana cultivation in the Nendran growing tracts of Trichur district also.

Though, this insect was reported from Assam in India as early as in the second decade of the century (Swiney, 1920 and Gupta, 1927), its occurrence in Kerala in an alarming proportion was just experienced during the late eighties only.

The O. longicollis is a robust reddish brown to black weevil which is present in the field through out the year in the North-eastern parts of India (Singh, 1966; Shukla and Kumar, 1969). The biology and bionomics of the weevil in West Bengal has been briefly described by Shukla and Kumar (1970) and Dutt and Maiti (1972).

Attacked plants are generally damaged by the weevil grubs riddling through the pseudostem to the peduncle and the badly

Plate 1. A typical weevil infested banana crop

a. Field view (cv. Nendran)

b. A weevil infested banana plant with partially mature bunch broken at the neck

a

b

affected plants snap at the base and fall of the stool in high winds. All most all commercial cultivars of the North-eastern India are susceptible to the weevil attack and the farmers suffer a heavy loss as the damage is more pronounced after the bunch formation. In Kerala also, the most important commercial varieties such as Nendran, Palayankodan and Poovan are found to be more prone to attack and the banana farmers on a plantation scale suffer a heavy loss.

As the insect is an internal borer and its early incidence is difficult to be detected, the pest damage goes unnoticed and the crop suffers a heavy toll. Moreover, the nature of the pest and the nature of the host plant and its fruit produce make the chemical and other means of control ineffective and hazardous.

No authentic information about this pest and its occurrence in Kerala is available. Therefore, a detailed investigation on the nature of damage, occurrence, morphology and biology of this pest and its preliminary control measures were undertaken during the present study. In this context, the following aspects were taken up to gather basic information about O. longicollis in Kerala to evolve a suitable management strategy against this potential banana pest.

1) Studies on the nature of damage, symptomatology, host plant association and varietal reaction to the weevil attack.

2) A brief account of the biological and morphological characteristics of both male and female weevils and its immature stages under laboratory conditions to facilitate the correct identification of the insect pest.

3) Morphometrics on the taxonomic features of the stages of the insect to elucidate the sexual dimorphism exhibited by the adult weevils.

4) Preliminary investigations on the control measures against the pest.

Review of Literature

2. REVIEW OF LITERATURE

The banana pseudostem weevil, Odoiporus longicollis Oliv., one of the serious pests affecting banana internationally, was known to be existing in the North-Eastern parts of India also. Recently, this pest has been found to be occurring in certain pockets of the Ernakulam district in Kerala causing serious threat to the banana cultivation. There is no information available as such in Kerala about the pest and its bio-ecology. All the available literature pertains to the North-Eastern areas of India and elsewhere in the world. Hence an attempt is made to review all the available information on the pest as described below.

2.1. Description of the pest

The adult weevil of O. longicollis is a robust one with black to reddish brown in colour having a size ranging from 15 to 20 mm in length excluding the snout. The insect is quite hardy and can withstand adverse conditions for a long time. The adults are less active and weak fliers. There is no apparent colour difference between the two sexes. The adult weevils are negatively phototropic preferring a dark, shady and humid condition always.

2.2. Prevalence and spread of O. longicollis

2.2.1. International occurrence in banana

One of the first reports on the weevil was made by Speyer (1918) when he recorded miscellaneous pests infesting plantain crop in Sri Lanka. In India, it was first reported by Fletcher (1914, 1916) from Bihar and Swiney (1920) from Shillong in Assam. Hutson (1921) also reported about O. longicollis and their serious occurrence in Sri Lanka and in Burma. Frogatt (1928) recorded that O. longicollis attacked all varieties of banana in Java and was found to be breeding in the stem tissues after the bunches had been cut or after the plants have got killed due to the attack of the rhizome weevil, Cosmopolites sordidus.

O. longicollis has been observed to be attacking the pseudostem of banana in Hong Kong and Hawaii Islands (Hoffmann, 1932). Jepson (1934) considered O. longicollis as one of the declared pests of banana in Sri Lanka but not as a serious one. However, Dias (1935) reported that C. sordidus and O. longicollis attacked the plantain crop only in the North-Western and South-Western provinces of Sri Lanka.

O. longicollis occurred throughout Formosa, where, it had become one of the most important pests of banana as recorded by Kung (1954). Later, Luo et al. (1985) reported from China that O. longicollis was one among the three species of curculionid pests infesting banana.

2.2.2. Prevalence in India

In India the incidence of the weevil in Assam was reported by Swiney (1920) and Gupta (1927). The occurrence of the weevil was first observed in Delhi by Batra (1952), though he reported that its distribution was restricted to a few gardens only. Singh (1966) reported that O. longicollis was observed on banana in Kattmandu valley and its adjoining areas. This pest was also found in the eastern parts of U.P. (Shukla and Kumar, 1969) where, the plantain crop was grown extensively.

2.2.3. Distribution in Kerala

No authoritative information is available about the pest and its occurrence in Kerala.

2.3. Ecological consideration

2.3.1. Altitude

Field observations as reported by Frogatt (1928) indicated that the borers were much active at altitudes of over 1000 feet above MSL. However, Uichanco (1936) found that the weevil infestation was confined to plantations at an altitude of over 2600 feet above MSL.

2.3.2. Seasons

As early as in 1928, it was recorded by Frogatt that the borers were more active and destructive during the wet monsoons.

Shukla and Kumar (1970) reported that, in summer, the adults represented 92 per cent of the total population, while, the larvae and pupae accounted for 6.5 and 1.5 per cent, respectively. In winter, the incidence of these stages were 95, 4.5 and 0.5 per cent, respectively. With the onset of rains the percentages altered to 60, 35 and 5 per cent, respectively.

Isahaque (1978) found that the dead banana plants remained succulent for a long time and therefore, permitted the survival of the larvae and pupae during the winter months. According to him, adults were more numerous during March-May and larvae during June-September, although, there was very little decline in the larval population during October-November.

Luo et al. (1985) observed that, the population densities of the weevil were highest from late May to mid June and from late September to mid October, when heavy damage was experienced. Overwintering larvae pupated in mid to late April and peak adult emergence was observed in late April and early May.

2.3.3. Temperature

The extreme temperature were unsuitable for the development of the weevil. Temperature below 8°C resulted in its inactivity while, above 35°C brought the death of the insect (Kung, 1964). The temperature ranging from 17 to 27°C were found to be the most suitable range for the normal activity of the weevil. At temperature

below or above this range, the life span was shortened to varying levels (Shukla and Tripathi, 1978).

2.4. Biology of O. longicollis

The investigations on the biology of the weevil were carried out by Fletcher as early as in 1914 at Pusa, Bihar. The longevity of the adult weevil which bored into the pseudostem was found to be extending upto two years (Fletcher, 1916). Pinto (1928) recorded that life cycle of the weevil occupied 26-30 days with the egg, larval, prepupal and pupal periods ranging from 3 to 4, 11 to 18, 3 to 6 and 7 to 10 days, respectively under laboratory conditions. Frogatt (1928) found that O. longicollis oviposited in the cut ends of the pseudostem or where, an injury permitted its entry into the centre of the stem. The larvae started feeding immediately in and around the bunch stalk and later spread through tissues of the leaf bases. Pupation took place in a thick tight cocoon made out of the fibres from the leaf bases.

Hoffmann (1932) reported, that the weevils were readily breeding under the laboratory conditions and completed its life cycle in about 6 weeks. He also observed that in the field, it bred almost throughout the year, probably, having several generations annually.

The detailed investigations on the biology of O. longicollis conducted by Kung (1955), showed that, the weevil had four or

more generations in an year and all the stages continued their development even during the winter periods. The eggs were usually laid singly in the stems under the leaf sheaths particularly in weak or injured plants or at the cut ends of the stems. The female laid upto 11 eggs with an average of 6. The larvae bored into the stems particularly in the upper parts and also damaged the fruit stalks. Pupation was near the surface of the stem in cocoons formed from the fibres. According to him the egg, larval, pre-pupal and pupal stages lasted for 5 to 12 days, 3 to 6 weeks, 3 to 7 days and 3 to 13 days, respectively during the February-April period and the newly emerged adults remained in the cocoon for 7 to 14 days. During September-October, the egg and larval stages lasted for 3 to 5 and 25 to 27 days, respectively. The ratio of the males to females among the adults collected in the field was about 2:3 (Kung, 1955).

Again, Kung (1964) observed that there were four or more generations of the weevil in an year in the laboratory and three or more in the field conditions. All the stages were found to be surviving throughout the year.

Laboratory and field studies carried out in West Bengal by Dutt and Maiti (1973) revealed that the eggs of the weevil were laid into the air chambers through the slits cut in the leaf sheaths. The pre-oviposition period, the incubation period, the larval period and the pupal period (including the adult pre-emergence

resting period of 4 to 6 days) lasted for 28 to 30, 3 to 5, 5 to 8, 26.2 to 68.1,. 20 to 24 and 21 to 44 days, respectively both in summer and winter.

2.5. Morphology

Information available on the morphological studies on O. longicollis are scanty.

2.6. Nature of attack and symptomatology

Pinto (1928) reported, that the adult weevils were found in the stumps or pseudostems of banana left on the ground after the harvest of bunches or under the dry sheaths hanging from the pseudostems or around its basal portion.

O. longicollis oviposited in the cut ends of the pseudostems or where, an injury permitted its entry into the centre of the stem. The emerging larvae fed immediately in and around the bunch stalk and later riddled through the tissues of leaf bases. Pupation took place in a thick tightly matted cocoon usually embedded in the tissues of the leaf bases (Frogatt, 1928). Hoffmann (1932) recorded that the oviposition of the weevil was neither visible nor he could be see where the eggs been laid, but he anticipated that the eggs were located in the pseudostem regions, where, it was got decayed or injured. The larvae tunnelled within the stem

and pupated in cocoons made by the fibres of the host plant (Hoffmann, 1932; Kung, 1955 and Kung, 1964). The fermentation and decay was more prevalent than the actual feeding injury by the grubs on the plants. Attack was accompanied and often associated by the presence of other insects. He also reported that the development could be completed even within a broken piece of the plant. When the heart was attacked near the terminal end, the plant always got killed.

Kung (1955) observed that the larvae bored through within the pseudostems particularly in the upper parts and also damaged the fruit stalks. It was also reported that the adults and larvae bored through the pseudostems, petioles and fruit stalks causing wilting and finally affected the flower and bunch emergence. The eggs were inserted into the inner surface of the sheath near the base of the leaf blade (Kung, 1964). He also recorded that the larvae passed through 4 to 7 instars. All stages were present in their maximum numbers in older plants after harvest (55%) at fruiting (30.2%) and before blooming (14.8%) of the total weevil population. The population density was inversely proportional to the vigour of the plant.

Shukla and Kumar (1970) conducted a detailed study and found that 70 per cent of plantains were infested in Uttar Pradesh. Both the larvae and adults caused damage by tunnelling into the pseudostem. The only outward traces of the damage were holes of 2 mm diameter approximately at equal distance apart upon the

pseudostems. He also observed that in older plants the holes were seen upto a height of 6 ft.

The damage due to larval tunnelling resulted in the breaking up of pseudostems at soil level, stunting and failure to produce fruits (Edward et al., 1973; Luo et al., 1985).

The infestation was more severe by the heavy feeding of the 4th instar grubs on the infested plantains (Lue et al., 1985).

2.7. Varietal response to pest infestation

There is hardly any information available with regard to the varietal reaction of banana plant to the weevil infestation in Kerala. The scanty reports from elsewhere are therefore, reviewed hereunder.

Frogatt (1928) recorded that O. longicollis attacked all varieties of banana and breed in the stem tissues after the bunch had been cut or after the plant got killed with the attack of Cosmopolites sordidus.

Dutt and Maiti (1973) from West Bengal reported that the banana varieties Martaman, Champa, Kanchakela and Kabuli were the most susceptible ones to the weevil infestation. The weevils preferred their oviposition sites on pseudostems with a circumference

of 25-50 cm; and at height upto 125 cm in tall varieties such as Martaman, Champa, Kanchakela etc., and heights upto 100 cm in dwarf varieties such as Kabuli etc.

A field survey carried out by Isahaque (1978) in Assam revealed that the varieties Malbhog and Chenichampa were highly susceptible both in the extent of damage and in the number of insects present. The variety, Bhimkal was completely free from attack, while, Kaskal was found to be fairly resistant. Resistance in these varieties was reported to be ascribed with their broad, thick and compact leaf sheaths and pseudostems.

2.8. Control measures

Because of the peculiar nature of the plant and the fruit produce, the control measures adopted against the pest are rather unsatisfactory. The various measures being suggested are as follows.

2.8.1. Cultural measures

The prophylactic cultural measures against the pest included the choice of a healthy site, good planting material, good sanitation in the plantations and rotation of crops for three years. Total destruction of badly infested plants and old plants by slicing them into smaller pieces and exposing to sun, hand picking of the adult weevils from traps made of cut stems were all found to be effectively reducing the survival percentage (Pinto, 1928; Kung, 1955 and 1964).

The most practicable control as suggested by Hoffmann (1932) consisted of clean cultivation and trapping the adults by means of pieces of stem on which they would oviposit, but were too thin to complete its development. Removal and burning of dry leaves, leafsheaths and dead or cut pseudostems in the winter also helped to reduce the population as proposed by Isahaque (1978).

2.8.2. Natural enemies

Muir and Swezey (1916) reported that a species of Chrysopila was widely feeding on Coleopteran and Dipteran larvæ infesting palms and banana. Jephson (1916) recorded that the C. ferruginosa attacked the larvae O. longicollis. Plaesius javanus Erich. was predacious on the larvae but had so far not been successfully established in Formosa, though it had been introduced several times (Kung, 1955).

Cannibalistic behaviour by the adult weevils on its own larvae even in the presence of food material (banana pseudostem) was described by Tripathi and Chaturvedi (1978) and therefore, they suggested that this behaviour might help in limiting the population of the pest naturally.

According to Luo et al. (1985) the natural enemies of the pest which could exert some control of the weevil population in the field were acarine and dermapteran predators.

Kung (1955) reported that Beauveria bassiana afforded useful control of the pest O. longicollis and gave upto 18.1 per cent mortality in a favourable weather condition.

Luo et al. (1985) also recorded that the bacteria Beauveria sp. act as an epizootic pathogen against the weevil grubs especially during wet seasons.

2.8.3. Autocidal control

Studies carried out in Formosa by Chiang (1965) on the male pupae of several species of insects including O. longicollis when exposed to X-rays and γ -rays at doses of 1000, 2000, 4000 and 8000 R revealed that the abberrations on the chromosomes of the germ cells increased with the radiation dose. When the pupae of one day old were irradiated, it was found that 50 per cent failed to give rise to adults and the adults that got emerged were deformed. Against O. longicollis the maximum practical dose was 2000 R for the sterile male technique which could be administered on three days old pupae of the same.

2.8.4. Chemical control

The available information on the chemical control of O. longicollis is again very meagre. Kung (1955) reported that in a field test against the ovipositing females, dieldrin (50% WP) when sprayed at concentrations of 0.25 and 0.17 percentage, gave 90 and

84 per cent mortality respectively, while, Endrin (19.5% EC) at the same [illegible] concentrations gave 88 and 80 per cent kills respectively.

Again, Kung in 1964 observed that dieldrin (50% WP) at 1:700 and endrin (19.5% EC) at 1:400-600 in water when sprayed several times after the rainy season prevented the oviposition of the weevils and gave added protection during late October and late November.

On susceptible banana varieties infestation might be controlled by a drench with endosulfan (35% EC) or carbaryl (50% WP) each at 0.1 per cent strength within the leaf whorls or on the leaf sheaths at monthly intervals during March-September (Isahaque, 1978). According to Luo et al. (1985), Decis (delta methrin) was found to be effective against the adult weevils, while, trichlorfon and dichlorvos were effective both against the adults as well as the larvae.

2.8.5. Biological control

The insect parasitic nematodes of the genus Neoaplectana under Heterorbabditidae are regarded as having an excellent potential as a biological control agent. Steinernema feltiae (Neoaplectana carpocapsae) also known as DD-136 nematode has been reported by various workers for the practical exploitation as an effective biocontrol agent (Weiser, 1954; Schmieg, 1964; Poinar, 1967 and Stanuzek, 1974) and has been reviewed by Poinar (1971 and 1979); Gaugler (1981) and Wouts (1984).

According to Poinar (1967), the cuticle of the nematode is very smooth, the head slightly rounded and lip slightly united. There were six outer cephalic papillae and six linear labial papillae. The pharynx was muscular and the anterior region of the procarpus slightly expanded. Metacarpus was devoid of valves and was followed by a basal bulb. Excretory pore was anterior to the nerve ring.

The nematode had six stages in its life cycle viz., egg stage, four juvenile forms and the adult. The infective stage juvenile were entering the host through the anal and oral opening as well as through the spiracles (Triggani and Poinar, 1976) as recorded in the case of large bodied insects and adult lepidopterans. Poinar (1979) reported that the insect mortality occurred within 24-48 h after inoculation, while, Danilov (1980) in the case of Galleria mellonella L. larvae found that this period was 15 h at a dosage of 5000 nemas per larva. Lysenko and Weiser (1974) studied the microflora associated with S. feltiae and reported that the bacteria, Pseudomonas maltophilia Hugh and Ryschenkovs and Xenorbabdus nematophiles achieved cent per cent mortality of the wax moth larvae five days after inoculation in association with the nematode. The success of DD-136 depended, as in the case of most microorganisms used in the biocontrol, largely on the environmental factors such as temperature and humidity.

The posibility of mass multiplication by both in vivo and in vitro methods had made Neoaplectanid nematodes, very popular

in biological control programmes. Dutkey (1964); Poinar (1971) and Blinova and Ivanov (1980).

Field trials involving S. feltiae for bio-control of crop pests yielded mixed results. In most cases, the unfavourable environmental factors had been pointed out as the major reason for its failure. Generally, the nematodes had been recommended for pests inhabiting cryptic habitates. Woutes (1984); Bedding (1984) and Kaya (1984) had reviewed the field trials involving entomogenous nematodes against, lepidopteran, hymnopteran and coleopteran pest species respectively upto 1980. And of late, Madhu (1989) reported that, eventhough, under laboratory conditions S. feltiae proved to be effective against the grubs of cashew stem borer Plocaederous ferrugineus, their efficacy under field conditions was not satisfactory.

Materials and Methods

3. MATERIALS AND METHODS

The investigations were carried out in the field and in the laboratory during 1989-90 on the following aspects of the Banana Pseudostem Weevil, Odoiporus longicollis Oliv.

1. Symptoms and nature of attack
2. The biology and morphology
3. Morphometrics of life stages and the sexual dimorphism of the adult weevil
4. Preliminary control measures against the weevil

3.1. Nature of attack and symptomatology

Infested plants both in the field and green house conditions were closely observed at various stages and the nature and symptoms of attack elucidated.

3.2. Biology

Biology studies on O. longicollis were carried out under laboratory conditions.

3.2.1. Maintenance of the culture

Rearing of the weevil was undertaken in concrete cement tanks kept under safe custody in the glass house condition. The stages of the weevil collected from infested fields were released

into these tanks. Pieces of banana pseudostem after harvest were used as feed for rearing the weevils. The banana pseudostem pieces kept in the cement tanks were changed at weekly intervals.

Observations were made by subjecting twenty replicates of each insect stage under normal room temperature and relative humidity. All life stages of the weevil were reared on small pieces of pseudostem of size 6 x 7 x 1.5 cm kept in petridishes of 7 cm diameter.

3.2.2. Determination of life stages

3.2.2.1. Egg period

Adult weevils were collected from culture tanks and males and females were separated based on the external characters (viz., markings on the rostrum and the size and length of beak). The sexes were fruther confirmed by dissecting out the internal genitalia in both sexes. A pair of male and female weevils were then released into fresh pseudostem pieces kept in petridishes of diameter 10 cm which were then kept in the rearing cages of size 50 cm^3 whose four sides were covered by glass and the upperside with iron net.

Oviposition sites were identified by the brownish coloured puncture marks and the eggs were then located and recovered from the air chambers of the leaf sheath.

The eggs were carefully transferred to a pseudostem piece of size 6 x 6 x 1 cm kept in a pair of petridishes of 7 cm diameter.

The petridishes were covered with a transparent polythene sheet of 100 guage to maintain the required humidity conditions.

3.2.2.2. Larval stage

Newly hatched larvae were carefully transferred to a new piece of pseudostem (of size 6 x 7 x 1 cm) and placed in a petridish of 7 cm diameter. The change in colour of the head capsule was observed daily, while, transferring the life stage to fresh pseudostem pieces. The larval stadia were determined based on the interval of the two successive moults as evidenced by the colour change of the head capsule. The observations continued till pupation along with daily change of host food.

3.2.2.3. Pupal stage

After pupation, the cocoons along with pseudostem pieces were kept in the petridishes until the adults got emerged. The duration of the pupal period was noted from the day of pre-pupal quiscence to the day of adult emergence out of the pupal cocoon.

3.2.2.4. Adult Stage

On emergence from the pupae, the sexes were separated as described in 3.2.2.1. The pairs were then kept in rearing jars of size (20 x 10 cms) and were provided with 20 g of freshly cut pseudostem piece. The feed was changed on alternate days. Longevity of the individual weevil was observed till their death under confinement.

3.2.2.4.1. Mating and ovipositional capacity

For studying the mating and ovipositional behaviour of the adults, separate sets were observed by maintaining freshly collected pupae from the culture tanks.

Freshly emerged adults from cocoons were sexed. Ten pairs of weevils were then introduced into the rearing jars. They were provided with fresh pieces of pseudostem @ 20 g per jar which was changed on alternate days. To provide darkness for effective mating, the jars were covered with black alkathene sheets. Mating behaviour was observed at two hour intervals. The pre-ovipositional period and the number of eggs laid were determined by observing the mated females separately.

3.3. Morphometry of the adult weevil

Morphological observations were made using a stereomicroscope with live and dead specimens. The adult specimens and the dissected body parts were processed by standard preservation and mounting techniques.

3.3.1. Processing technique

Various body parts of the insect were dissected out and transferred into 250 ml beaker, into which 10 per cent KOH was poured and boiled for 30 minutes and repeated the same for two to three times until got cleared.

After clearing, the specimens were washed in tap water and transferred to acetic acid for 3 minutes. They were then transferred to carbol-xylol (1:3) mixture and kept overnight. These were then transferred to xylol for dehydration. Canada balsam was used as the mountant. The slides were later labelled and stored in slide trays for morphometry and photography.

3.3.2. Biometric and morphometric measurements

The body length of the adult from the anterior tip of the snout to the apex of the abdomen along the middorsal line and the body width at the maximum point across the area of the folded elytra were measured.

Maximum length of the rostrum from its base to the apex of the rostrum and width in the middle most region were recorded. Length of the thorax was measured from the base of the rostrum to the anterior margin of the elytra and width across the middle line of the thorax. Length of the elytron was noted from its apex to the base and the width across the region at one third distance from the anterior margin.

Measurement of the length of leg was made from the attachment point of the coxa to the distal end of the claw.

Length of the antenna was taken from the base of the scape to the apex of the club.

Measurement of length, width and weight of each instar larvae (10 replicates) were also taken. The length was measured from the anterior margin of the head to the apex of the anal region and the maximum width across the middle most region of the larva.

3.3.3. Sexual dimorphism of the adult insect

3.3.3.1. Morphometric studies were separately made on the adult individuals of each sex on the following aspects:

1) Total length and width of the body.
2) Length and width of the rostrum, head, thorax, abdomen, elytron, hindwing and legs.
3) Character of the antennal segments and their individual observations both under the compound and scanning microscopes.
4) Elytron and hindwing measurements and the pattern of the venation.
5) Measurements of the individual segments of the three pairs of legs.

3.3.3.2. Statistical procedure to determine the sexual dimorphism utilizing certain morphological characteristics

Among the various characters studied above, the most critical parameters which were to be reckoned with importance were found to be the position of the antennal socket (As), Rostral length (Rl), Rostral width (Rw), Head capsule length (Hcl) and Head capsule width (Hcw).

A measure of central tendency to characterise certain data behaviour can be utilized for the biological studies especially for determining morphometric variations. This method is utilized here especially to determine sexual dimorphism (Rao, 1983) in cases, where the sex determination is rather difficult by external looks.

The criteria for determination of sex were arrived as follows. The various characters of the insect such as position of the antennal socket, rostral length, rostral width, head capsule length and head capsule width were found to be of relative importance in the determination of sex. Hence, a set of criteria for the determination was arrived at as As, Rl, Rw, Hcl and Hcw in the descending order of their relative importance. In certain cases, there might be chances, that the measurements of a particular insect may not be in full agreement with the criteria already fixed and hence a confirmatory set of criteria were found to be essential.

As the thoracic length (Tl), thoracic width (Tw), abdominal length (Al) and abdominal width (Aw) were of next relative importance, the confirmatory criteria were arrived at as Tl, Tw, Al and Aw.

The data obtained from the random sample, collected and measured would be classified according to sex and afterwards reclassified according to the criteria and confirmatory criteria as described above.

The values for the parameters described above were taken as the mean of the maximal values for the male and the minimal values for the female weevils. The observations of a particular insect would be recorded in the sequential way as per the criteria described earlier and would be first matched with the above determined criteria. If all the values fell below the criteria level, the insect might be classified as a male and if above the same it might be considered as a female. In case, there is any discrepency regarding one or two measurements, the confirmatory criteria would be taken into consideration and the sex should be re-confirmed in the same way as per the first criteria.

3.3.3.3. Electron scanning microscopy

External morphological characters studied through the stereo-microscopic observations revealed certain textural patterns or punctuations on the rostrum, thorax and the elytra which were further resolved through electron scanning microscope and photographic plates prepared.

The specimens were processed by standard technique for the scanning purpose under the electron scanning microscope. The procedure for the processing was summarised below.

(1) Preparation of buffer solution

The buffer solution was prepared as follows:

(a) Monobasic sodium phosphate $NaH_2PO_4 \cdot 2H_2O$

(31.202 g in 1000 ml distilled water)

(b) 0.2 molar Dibasic sodium phosphate $Na_2HPO_4 \cdot 2H_2O$

(71.628 g in 1000 ml distilled water)

Add (1) 19 ml + (2) 81 ml to get the 100 ml buffer solution.

(2) Fixation of specimens

The fixative was made by adding 1 ml of 2.5 percent glutaldehyde solution to 9 ml of buffer solution prepared as above and the specimens were kept in the mixture for 24-48 h for fixing.

(3) Dehydration

The specimens after fixation in the buffer solution were washed in a series of changes of acetone or alcohol solutions for different time intervals as shown below:

i) 50% acetone/alcohol in water - 25 minutes

ii) 70% '' - 20 minutes

iii) 90% ,, - 1 hour

iv) 90% ,, - Overnight

v) 95% ,, - Twice for 25 minutes each

vi) 100% ,, - Thrice for 30 minutes each

Such processed specimens were kept over cellophane paper sheet and placed on the stage of microscope and subjected to Electron scanning process in the instrument.

3.4. Preliminary control studies

3.4.1. Varietal screening under field conditions

Fifteen varieties were planted in the farmers field at Kainthikara, Alwaye on 19-8-89 as an observational field trial. This area was selected because of the high incidence of the weevil damage consecutively for the last few seasons. Five replications were maintained for each variety. Recommended mannurial and cultural practices were followed to raise the plants for the experiment. Adjoining the experimental field there were large scale planting of the susceptible varieties of Nendran, Palayankodan etc. Observations were commenced from 3rd month onwards and continued at monthly intervals, till harvest on, the weevil incidence, damage and for any symptoms of attack.

3.4.2. Varietal screening under net house condition

The following recommended cultivars of the banana were raised as a pot culture under sealed net house conditions to prevent the escape of the released insects to outside. Varieties tried were Palayankodan, Njalipoovan, Chenkadali, Poovan, Kanchikala and Karpooravally. Three replications were maintained for each variety.

The banana suckers were planted in cement pots of 1 m x 50 cm x 2 cm size and were filled with 1:1:1 mixture of sand, soil and organic manure. All the cultural practices were followed as per the package of practices recommendations (Kerala Agricultural University, 1987).

The pseudostem portion of each plant was covered with a nylon net at three months after planting and tied and secured at both the neck as well as the base region of the plant. Wooden sticks in a cross like pattern were tied inside the net to make it spread apart.

Inside the nettings, three pairs of freshly emerged male and female weevils each were released and confined to ensure uniform exposure of the plants to infestation. Plants under observations were inspected at weekly intervals with respect to weevil mortality, ovipositional punctures, gum exudations, bore holes, tunnelling, buckling of the leaf stalk, lodging of the pseudostem portions etc.

3.4.3. Chemical control studies

3.4.3.1. Preventive protection with natural products

Observational trial on the efficacy of neem oil suspension and fish oil soap insecticide (FOIS) against the pseudostem weevil were conducted under field conditions in a farmers plot at Alwaye.

Neem oil suspension was prepared by dissolving 60 g soap dissolved in 1 litre of water and mixed with 40 ml of neem oil and 10 ml of sticker. Stirred well and allowed to get a clear suspension.

Fish oil soap (FOIS) was prepared by adding 300 g of FOIS and 20 ml of sticker in 2 litres of water. Stirred well and

allowed to clear off the suspension. After settling the particles the supernatent liquid was used for spraying purpose.

Both these suspensions were applied with a High volume sprayer on an *in situ* crop in the farmers field. For the test spraying two susceptible varieties namely Palayankodan and Nendran at both pre-flowering and post-flowering stages were selected each replicated thrice.

3.4.3.2. Curative protection

3.4.3.2.1. Padding technique using dichlorvos

This technique was tried as a curative treatment of an already infested plant using dichlorvos, a least residual fumigant insecticide. Three heavily infested plants bearing bunches each of Palayankodan and Nendran were selected for the padding technique, on three regions of the pseudostem, viz., basal, middle and top portions in a spiral manner.

Incisions were made and a pad of tissues of size 5 x 5 x 2 cm were removed. The square cavity thus made was immediately stuffed with cotton pads. Then the cotton pad was soaked with the proprietory dichlorvos insecticide solution as such by using a filler. Afterwards, the cavity with the treated cotton pad stuffed inside was covered over by the flap of the cut out leaf sheath. It was then mud plastered and secured tightly with plastic gunny bags.

The dosage of dichlorvos tried was 2.5 ml per pad per incision and the total being 7.5 ml per plant through three incisions. The treated plants were observed after 7 days to determine the efficacy and the level of infestation.

3.4.3.2.2. Injection technique both in the pseudostem and also in the rhizome regions

The holes of size 5 cm in length and 0.5 cm in diameter were made on the pseudostem and rhizome regions at an angle of 45° at three positions spirally around the same. The holes were made with the help of a cork screw borer. Through the hole thus made, a systemic insecticide viz., monocrotophos coupled with rhodamine B dye to track the movement was injected with a pipette. The quantity of the insecticide injected through the pseudostem and rhizome was 2.5 ml per bore hole.

3.4.3.2.3. Root feeding technique

Four healthy roots were excavated without any physical damage, out of which two roots were excised at their tip and two roots with intact rootcap. All these roots were inserted into 10 ml bottles containing the insecticide dye mixture.

3.4.4. Biological control studies with the parasitic nematode DD-136 on O. longicollis

3.4.4.1. Culturing of the parasitic nematode

The parasitic nematode popularly known as DD-136 with the

scientific name Neoaplectana carpocapsae was renamed under the Steinernematidae family with the genus Steinernema.

The nematode nucleus culture for the study was obtained from Department of Nematology, Tamil Nadu Agricultural University, Coimbatore and was mass multiplied in the laboratory using in vivo methods.

Larvae of rice moth, Corcyra cephalonica Strain. maintained in the laboratory for the purpose were used. A slightly modified version of Dutky's method (1964) was adopted. About 25-30 final instar larvae of the rice moth were washed in 0.01% formalin and placed in a sterilized standard petridish (9 cm diameter) containing two moist filter paper to serve as an infection chamber. A 3 ml suspension of the infective stages containing 300 nematodes per ml was added in the infection chamber. It was then covered by a polythene bag (100 guage) and wetted inside to keep away saprozoic flies. These petridishes were then incubated at room temperature in a water bath for ten days within a B.O.D. incubator.

The freshly developed nematodes were obtained by using a nematode collecting dish similar to the one described by White (1927). The lid of the small petridish (3 cm diameter) was placed upside down on the bottom of a larger petridish and was covered with a filter paper. Formalin 0.01% was filled up to the half level of the small petridish kept in the larger petridish.

The dead and parasitised larvae were placed radially in the middle of filter paper. The entire collecting dish was placed in a water bath and covered by a bell jar and kept in a B.O.D. incubator. The infective juveniles emerging from the cadaver migrated into the formalin to form a suspension which was collected on alternate days. The nematode culture suspension thus collected was stored in sterilized dark brown bottles kept at 5-7°C in a refrigerator.

3.4.4.2. Infectivity studies on the parasitic nematode on the weevil grubs

The cultural weevil grubs were classified into their respective instars based on their body measurement viz., body length, maximum body width and body weight.

3.4.4.3. Preparation of nematode suspension

Nematode suspension of concentrations 10, 100, 500 nemas per ml were prepared from the stock suspensions collected from the nematode extracting dishes after counting the number of nematodes in it. The volume was made up with 0.01% formalin solution.

3.4.4.4. Determination of nematode inoculum load showing the grub mortality

The prepared nematode suspension of known nemas per ml was poured on the previously weighed grubs using 1 ml pipette. Five grubs were kept under each treatments. The inoculated grubs

were kept in petridishes lined with filter paper moistened with 0.1% formalin solution and covered with plastic bags. The inoculated grubs were placed in an incubator at 25-30°C. Observations on the mortality was made on alternate days and the dead grubs were removed to collecting dishes as described earlier. From the collecting dishes 0.1 ml of the nematode suspension was taken and the number of nemas per ml was determined at different intervals.

3.4.4.5. Bioefficacy of nematodes under field conditions

Pseudostem weevil infested banana plants with live stages of the pest were located and the nematode suspension at 50, 100, 500 nemas per ml were injected into the tunnels with a pipette at the rate of 10 ml per bore hole in the pseudostem and plugged with mud. Two varieties namely Palayankodan and Nendran at both pre-flowering and post bunching stages were selected for the nematode injection. Under each variety three plants each were inoculated with each nematode suspension. The plants were examined one month after inoculation by cutting open the riddles and burrow holes on the pseudostems, where the inoculation was actually made and the mortality of weevil grubs assessed.

Results and Discussion

4. RESULTS AND DISCUSSION

4.1. Symptoms and nature of attack

The extensive investigations conducted both in the field and green house conditions revealed the following nature of attack and symptoms of infestation by the weevil on the banana crop.

4.1.1. Under field conditions

The banana plant was generally observed to be getting infested from the 4th month onwards after planting coinciding with the peduncle formation. From outside, the earlier symptoms of attack were not visible except for the small oviposition holes/punctures made by the weevil probably meant for the gaseous exchange (Dutt and Maiti, 1972). The holes were circular in outline with their boundaries brownish in colour and approximately 2 mm in diameter. The holes were normally observed on the pseudostem portion at a height ranging from 15 cm above ground upto the neck region of the plant depending upon the degree and stage of the attack. These observations were in conformity with Shukla and Kumar (1970). The eggs were deposited in the air chambers especially on the outer sheaths of the pseudostem at the rate of one egg per chamber.

The grubs emerging from the eggs deposited in the air chamber immediately started feeding on the parenchymatous tissues and bored

into the inner sheaths causing extensive riddling. The bore holes exhibited gum exudation in the initial stage and the dried exudate got externally collected at the outer regions. This gummy exudation indicated the probable location of the internal tunnels. The tunnelling extended both towards the base as well as towards the distal end of the plant from the point of entry and thereby weakening the pseudostem. At later stages, all the tissues damaged by the grubs within the tunnels decomposed and resulted in the total collapse of the pseudostem. These observations were also reported by Frogatt (1928); Hoffman (1932); Kung (1955) and Kung (1964). Advanced stages of the sheath boring by the grubs resulted in the shortening of leaf petioles, yellowing of lamina and finally the breakage of the leaves at the petioles. Such badly riddled plants normally broke at the pseudostem portion even if the plants were propped. The plants which were not lodged even with the riddling within the leafsheath and partial boring into the peduncle showed delayed flower emergence and resulted in the formation of undersized bunches. Some of these observations were also recorded by Kung (1964); Dutt and Maiti (1973); Edward et al. (1974) and Luo et al. (1985).

In all the areas where the survey was made, revaled that almost all the varieties under cultivation were found to be susceptible to the weevil attack. The common cultivars viz., Nendran, Palayankodan and Poovan were highly susceptible, while, the lesser known varieties viz., Njalipoovan, Karpoorvally and

Plate 2. Field symptoms at different stages of attack by *O. longicollis*

a. Oviposition punctures made by the adult weevils

b. Initial bore hole on the pseudostem by the grubs

a

b

Plate 2. Field symptoms at different stages of attack by *O. longicollis*

c. Initial boring by the grubs into the peduncle

d. Advanced stages of tunnelling by the grubs into the peduncle

c

d

Pate 2. Field symptoms at different stages of attack by O. longicollis

e. A totally destroyed plant broken at the neck

f. Petiole boring by the grubs and gummosis

e

f

Kunnan were found to be less damaged. In 1972, Dutt and Maiti from West Bengal reported that the local varieties Martaman, Champa, Kanchakela and Kabuli were the most susceptible ones. Isahaque (1978) in his field survey in Assam reported that the varieties Malbhog and Chenichampa proved to be highly susceptible, while, Bhimkal variety was reported to be free from the infestation. The prevalence of the attack was found to be almost throughout the year in all these tracts, especially, around Perumbavoor, Kalady, Kolencherry, Vazhakkulam, Alwaye and Parur regions.

4.1.2. Under green house conditions

Under confined conditions in the green house, it was observed that apart from the above mentioned symptoms and nature of attack (para 4.1.1.) it was also noticed that the grubs moved further upwards and started boring into the tissues of leaf petioles particularly in the variety Chenkadali. During the initial phase, there was profuse exudation of gum which was found to be oozing out and then got collected within the leaf whorls (Plate 2.f). Later on, the petiole and lamina turned yellowish and withered within a period of one month after the tunnelling and the consequent gum exudation on the petioles.

4.2. Biology

The behaviour and duration of different life stages of the

Plate 3. Life cycle of O. longicollis

1. 1st instar grub
2. 2nd instar grub
3. 3rd instar grub
4. 4th instar grub
5. 5th instar grub

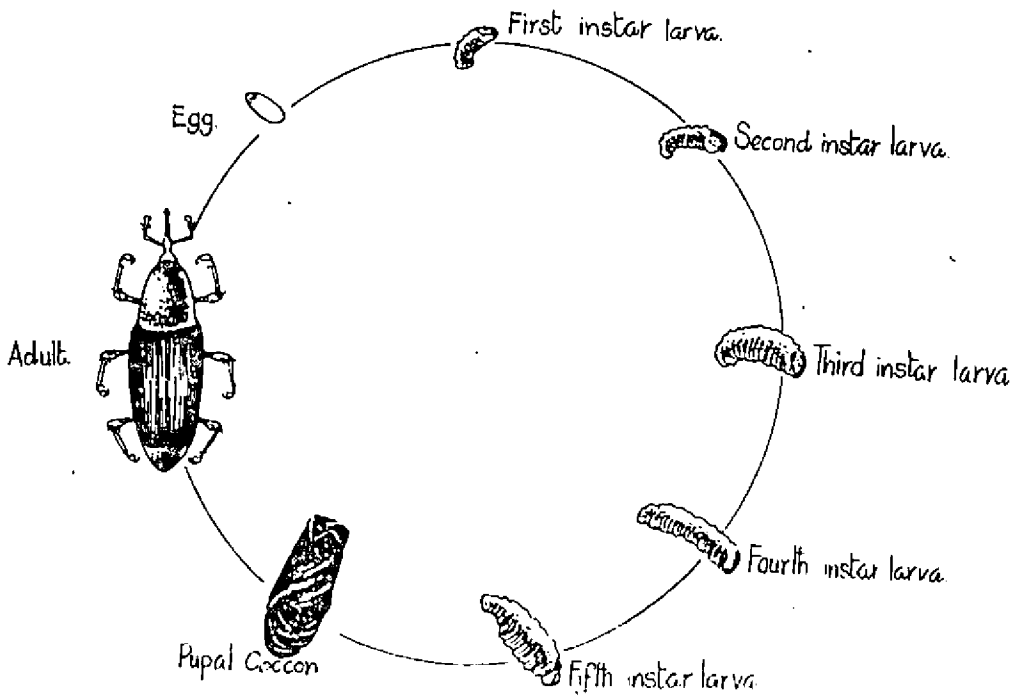
A - Adult weevil
B - Egg
P - Pupa


1
2
3
4
5
E
A
P

Table 1. Duration of different life stages of O. longicollis under laboratory conditions

Sl. No.	Period (days)			
	Egg	Larval	Pupal	Adult
1	2	23	10	149
2	2	19	13	157
3	2	22	11	168
4	3	24	10	145
5	2	19	12	233
6	2	20	11	159
7	3	21	10	148
8	2	20	11	169
9	3	19	12	175
10	2	20	12	198
Mean	2.3	20.7	11.2	170.1

Fig. 1 . Life cycle of O. longicollis Oliv.



insect were worked out under known conditions in the laboratory and the details observed are presented in Table 1.

4.2.1. Egg

Eggs were laid singly by the female weevil by inserting its ovipositor through the ovipositional slits cut with the rostrum on the outer epidermal layer of the leaf sheath down into the air chamber (Plate 4). These air chambers were regularly arranged squarish empty spaces within the leaf sheaths bounded by parenchymatous tissues. When cut portions of the pseudostem were offered for oviposition, the weevils did not cut the oviposition slits, instead, they oviposited through the soft parenchymatous wall of the air chamber.

Ovipositional slit was more or less round in shape with its mouth remaining uncovered. Eggs were yellowish-white in colour, smooth and almost cylindrical in shape with rounded ends. The eggs were found to posses a prominent area of air space within it at one of its ends. The incubation period ranged from two to three days with a mean of 2.3 days at a mean minimum and maximum temperatures of 28 and 32 degree celcius respectively. These observations were in partial agreement with the findings of Dutt and Maiti (1972) who reported an incubation period of 3 to 5 days at 32° to 35°C. Pinto (1928) and Kung (1956) also recorded incubation period as 3-4 days and 3-5 days, respectively under Subtropical condition. Therefore, the type species under study showed

Plate 4. A weevil egg deposited within the air chamber of the leaf sheath

a relatively lesser incubation period as compared to the North-eastern types and of elsewhere.

4.2.2. Larvae

All the larval stages were found to be apodous, soft, fleshy, sub-cylindrical, wrinkled and covered with sparse brownish setae of varying lengths. Mid-abdominal segments were wider than the caudal and thoracic segments. The anal plate was provided with four setae posteriorly on either side. These results were also reported by Dutt and Maiti (1973).

Larval period lasted for 23-29 days with an average of 20.7 days. The observation made by Pinto (1928) with a larval period of 11-18 days and by Dutt and Maiti (1973) with 20 to 24 days showed that there was a slight difference in the range of larval duration, which might be due to pronounced seasonal influence experienced under the North-eastern regions where compared to the mild conditions in Kerala.

There were five distinct larval instars which lasted for 2-3, 4-7, 4-6, 5-7 and 6-8 days respectively at a mean temperature range of 26-32°C. The fifth instar was the most prolonged one, which included the prepupal stage also.

The fifth instar larvae during the pre-pupal stage, made a cocoon by winding short pieces of fibrous material around its body, which were cut out from the leafsheaths. An unusual habit

of the larva was observed towards the fag end of its pre-pupal stage that it apparently sealed the head end of the fibrous cocoon. It was cutting small pieces of fibres from the hard outer side of the leafsheath, within the reach of its head. During this process, somewhat an irregularly rectangular shaped hole was made on the outer sheath. This habit as reported by Frogatt (1928) was also observed under our conditions too.

4.2.3. Pupa

The pupa was exarate and pale yellow in colour and formed within a fibrous cocoon. The cocoon was found at the end of the larval tunnel, invariably towards the periphery of the pseudostem. However, it was rarely found in the outermost sheath but embedded within the next inner layers. The cocoon was found to be positioned along the axis of the leafsheath but never across it. If the larval width was more than the maximum width of the leafsheath, cocoon formation took place within two or more adjacent sheaths in its longitudinal axis. Head end of the pupa within the cocoon remained directed towards the basal end, possibly to get freedom from geotropic effects.

The pupal period including the pre-emergence resting period of the adults lasted for 10 to 13 days with an average of 11.2 days. However, a wider range of the pupal duration as reported by Kung, 1955 (3 to 13 days); Pinto, 1928 (7 to 10 days) and also

by Dutt and Maiti, 1973 (20 to 24 days) showed that there existed a considerable variation in the life stages among different ecotypes. The pre-emergence resting period was found to be varying from 2 to 4 days during which time, the hardening and pigmentation of the body cuticle and the wings took place.

4.2.4. Adult

The adults immediately after emergence were brownish in colour and later turning to browninsh-black to black. The emerged adults were observed to be negatively phototropic preferring a dark and humid condition. They often remained within the pseudostem usually in between two sheaths or around the shady portions of the pseudostem.

It was also found to be taking shelter within the decomposing tissues of the damaged and fallen pseudostems. They fed on the undamaged tissues of the leafsheath preferably from the inner surface and also on the decomposing tissues. Adult weevils were weak fliers, but were observed to be crawling rather swiftly on the ground as well as around the pseudostems. The adult longevity, under captive feeding was found to be ranging from 145 to 238 days with an average of 170 days. Even under starved conditions, the adult weevils were observed to be surviving for 1 to 2 weeks at the maximum under lab conditions. This showed the importance of crop fallowing in the management of the pest as well as the complete

removal and destruction of the crop residues in the field at least for a period of one month.

Mating tendency was exhibited by the adult weevils two to three days after their emergence from the cocoon. During the mating process, the female carried the male on its back and walked slowly with its antennae moving briskly. This dorsal riding lasted for 5 to 10 minutes and afterwards the actual copulation took place which was found to be lasted for 5 to 6 minutes. It was also observed that the weevils were effecting multiple mating periodically during both day and night.

After effective mating, the pre-oviposition period was recorded to be ranging for a period of 12 to 19 days. Considerable development of the reproductive organs took place during this period of pre-oviposition. The total number of eggs laid by the female after one mating period from 6 to 12 with an average of 9 eggs as shown in Table 2. However, Kung (1956) reported that it was laying a maximum of 17 eggs with an average of 6 eggs per mating which again showed the considerable bionomic variation of the type available in our tract.

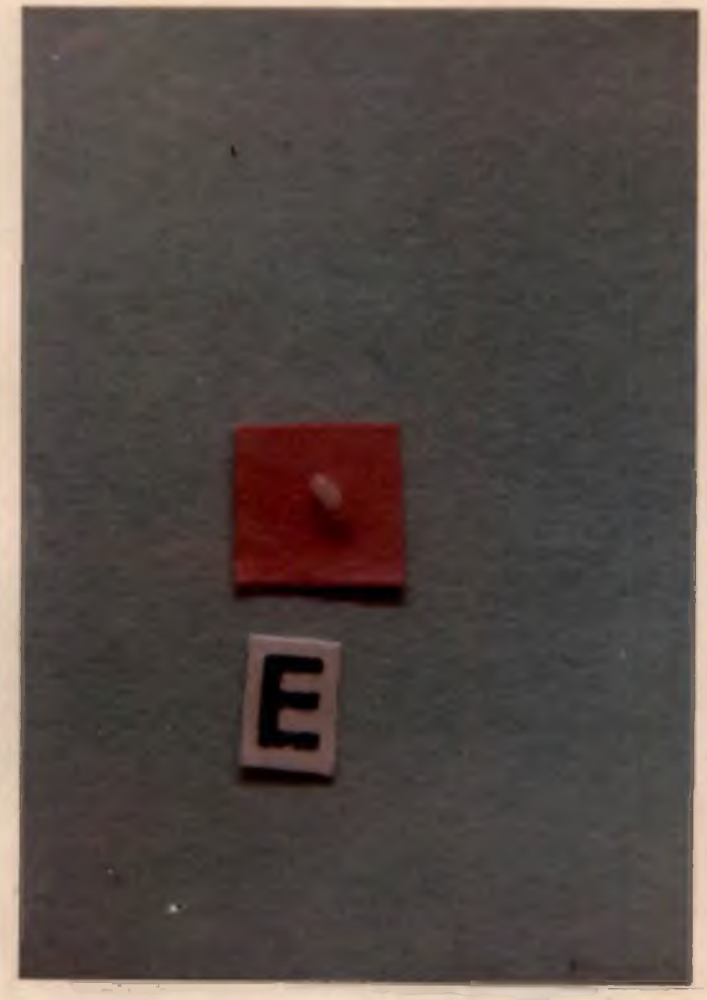
4.3. Morphology and morphometrics

Based on the external morphology the various morphometric observations were recorded under laboratory conditiors and the details are furnished below with respect to different stages of the insect (Table 3).

Table 2. Ovipositional capacity of the female weevil of O. longicollis after single mating under laboratory conditions

Sl. No. of female weevil observed	Egg deposited
1	6
2	5
3	10
4	11
5	13
6	8
7	9
8	12
9	11
10	12
Mean	9.7

Plate 5. A typical weevil egg with prominent air space


E

4.3.1. Egg

Eggs were smooth, about cylindrical in shape with rounded ends having a prominent area of air space at the anterior region (Plate 6). Each egg measured 2 mm in length and 1 mm in diameter, on an average.

4.3.2. Grubs

The body of the freshly emerged larva was creamy white with an yellowish orange head. The body segmentation was indistinct. The mean body length and width were 3.75 and 1.32 mm respectively. The head capsule, on an average, measured 0.9 mm in width. The reddish brown mandible had an average length of 0.18 mm as shown in Table 4 and was bidentate and heavily sclerotized.

Second instar larva measured 6.25 mm in length and 1.75 mm in width. The head capsule, on an average was having a width of 1.44 mm, while the mandible was 0.2 mm in its length.

The third instar larva had a mean length of 12.57 mm and a width of 2.78 mm. The head capsule width was 1.54 mm while, the mandible length was 0.27 mm.

The fourth instar larva had a mean length of 13.38 mm and a width of 3.38 mm. The head capsule width of the same was 1.74 mm, while, its mandible length was 0.33 mm.

Table 3. Morphometrics of the immature stages of O. longicollis*

Stage	Length (mm)			Width (mm)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
A. Egg	2	2	2	1	1	1
B. Grubs						
I instar	4	3	3.75	2	1	1.32
II instar	8	6	6.25	3	1.3	1.75
III instar	13	10	12.57	3	2	2.78
IV instar	14	12	13.38	4	3	3.38
V instar	20	17.5	18.41	6	4	4.95
C. Pupa	35	30	32.2	15	10	12.73

* Average of 10 replicates

Fig. 2. The relative size variation in the five instars of O. longicollis grubs

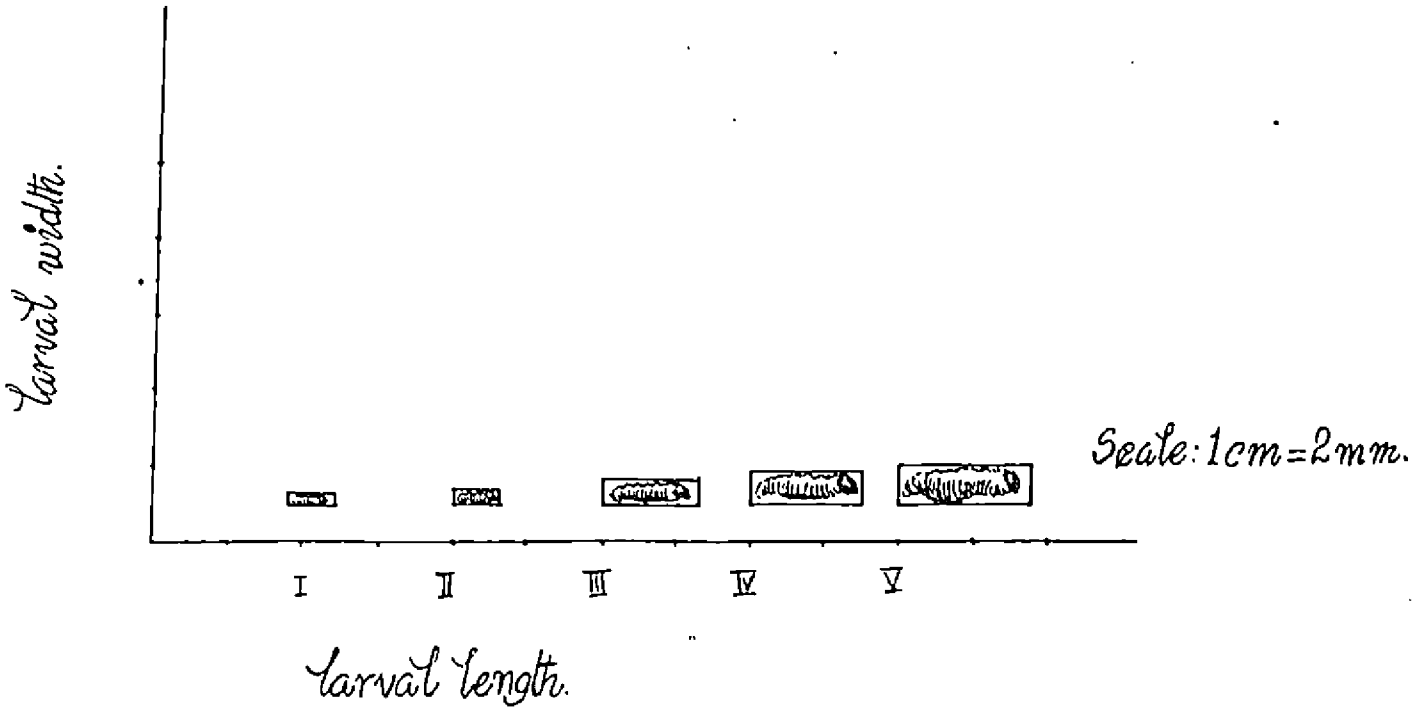


Table 4 . Morphometrics of the Head capsule and mandible of O. longicollis (grubs)*

Grubs	Width of Head capsule (mm)			Length of mandible (mm)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
I instar	1.2	0.89	0.9	0.2	0.15	0.18
II instar	1.59	1.25	1.44	0.21	0.20	0.20
III instar	1.61	1.45	1.54	0.30	0.23	0.27
IV instar	2.00	1.60	1.74	0.38	0.21	0.33
V instar	2.28	1.68	2.09	0.47	0.30	0.42

* Average of 10 replicates

The fifth instar larva had a length of 18.41 mm and a width of 4.95 mm. The head capsule width was 2.09 mm and the mandible length was 0.42 mm.

4.3.3. Pupa

The pupal cocoon was having a mean length of 32.2 mm and width of 12.73 mm, while, the actual pupa without its cocoon was having a mean length of 15.2 mm and width of 10.34 mm. The results are almost in conformity with the morphometric observations as recorded by Dutt and Maiti (1973).

4.3.4. Adult

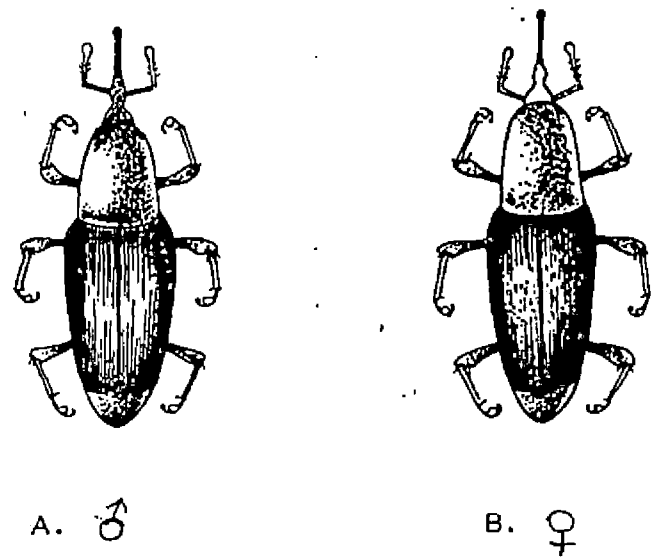
Measurements of different body parts of the adult weevils are presented in Table 5 . The data clearly showed a marked variation between the sexes which, therefore, exhibited a clear case of sexual dimorphism both morphologically and morphometrically.

Mean length and width of male and female insects were 15 and 5 mm and 19 and 5.2 mm, respectively. Females were invariably found larger than the males in all sets of observations (Fig.3).

4.3.4.1. Head

Head was round with an anteriorly extending rostrum or beak. The eyes were oval and were situated towards the base of the rostrum.

Fig. 3 : Adult stage of O. longicollis



A. ♂ B. ♀

Mouth parts were vestigial and were enclosed in the terminal aperture of the rostrum. Only mandibles could be visible externally. Mouth parts were of the chewing and biting type.

4.3.4.1.1. Rostrum

Rostral punctuations were more pronounced in males than in the females and each punctuation was placed on a slightly raised area as evidenced by the electron scanning microscopy (Plate 6). The number of such punctuations per linear unit length of the rostrum was more in males than in females, giving the rostral surface a rough appearance in the former. Absence of raised areas and small and widely spaced rostral punctuations were characteristic of the females giving the rostral surface a smooth appearance. These results are also in conformity with Dutt and Maiti (1971) and also the difference in the sexes as reported by Marshal (1916) that the rostrum of the male is nearly always more coarsely punctuated and the punctuations extended nearly or quite upto the apex, whereas, in the female, the apical half or more was very finely punctuated or even quite smooth.

Rostrum in female was significantly larger than that of the male. The mean length and width of the rostrum in the female were 4.24 and 0.51 mm and that of the male were 3.84 and 0.49 mm respectively (Table 5).

Plate 6. Electron scanning photographs of the male and female weevils of *O. longicollis* highlighting the difference of punctuations on the rostrum

a. ♂

b. ♀

a

b

Table 5. Morphometrics of the adult stage of O. longicollis*

Body part/parts of the insect measured	Length (L)/ width (W)	Measurement (mm)				Calculated t C.D. Table value t_{18}=2.101
		Male		Female		
		Range	Mean	Range	Mean	
a. Adult Body	L	15.1-14.9	15	19.1-18.9	19	
	W	5.1-4.9	5	5.1-4.9	5	
b. Antenna	L	0.15-2.35	3.82	0.1-2.35	3.79	1.16
i) Scape	L	0.15-0.20	0.16	0.1-0.15	0.125	0.208
ii) Funiculus	L	1.45-1.55	1.51	1.5-1.85	1.645	0.78
iii) Club	L	2.0-2.35	2.13	1.65-2.35	2.02	-0.12
c. Rostrum (base to top)	L	3.6-4.0	3.84	3.5-4.5	4.24	0.21
	W (midpoint)	0.45-0.5	0.49	0.45-0.60	0.51	0.085
d. Position of the antennal socket on the rostrum	L	0.75-1.00	0.78	0.35-0.60	0.54	0.75
e. Thorax	L	4.5-5.2	4.93	4.5-6.3	5.24	-0.13
	W	3.5-4.8	3.99	2.2-4.0	3.66	-0.33
f. Abdomen	L	7.5-8.3	8.04	7.3-9.1	8.62	0.159
	W	5.0-5.8	5.3	4.4-5.3	4.88	-0.18
g. Elytra	L	5.7-7.0	6.57	6.3-7.2	6.92	0.10
	W	2.5-3.0	2.74	3.0-3.4	3.16	0.302
h. Hind wing	L	12.75-13.6	13	13.5-14.5	14	0.15
	W	1.99-3.25	3	3.9-4.1	4	0.60

* Average of 10 replicates each

4.3.4.1.2. Atenna

The antenna were reddish brown in colour. It was inserted at a mean distance of 0.78 mm away from the base of the rostrum in the case of males and 0.54 mm in the case of females. The mean total length of male antenna was 3.82 mm, while, that of the female was 3.79 mm. Scape was elongate and slender towards the base and swollen apically. Funiculus was six segmented. The first and second segments were swollen and slightly elongated relatively (Fig. 4). The other four segments were more or less equal in length and some what bead like. The fifth and sixth segments were sparsely pubescent. The mean length of funiculus was 1.645 mm in female and 1.51 mm in male weevils. The club was elongate and oval shaped with fine pubescence having a length of 2.02 mm in female and 2.13 mm in male (Table 5).

4.3.4.2. Thorax

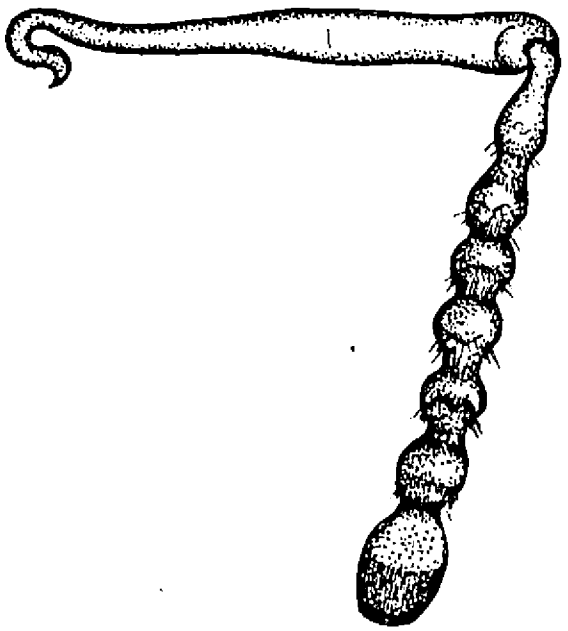
The meso and metathorax were fused together with the notum which remained as a shield above. The male thorax was having a mean length of 4.93 mm and a width of 3.99 mm, while, that of the female thoracic region was having a mean length of 5.24 mm and width of 3.66 mm. The thoracic region in females was therefore, larger than that of the male which again showed clear size difference between the sexes (Table 5). The notum on its peripheral sides exhibited punctuations which were very feable and therefore, indistinct between the sexes.

Fig. 4 . Antenna of O. longicollis

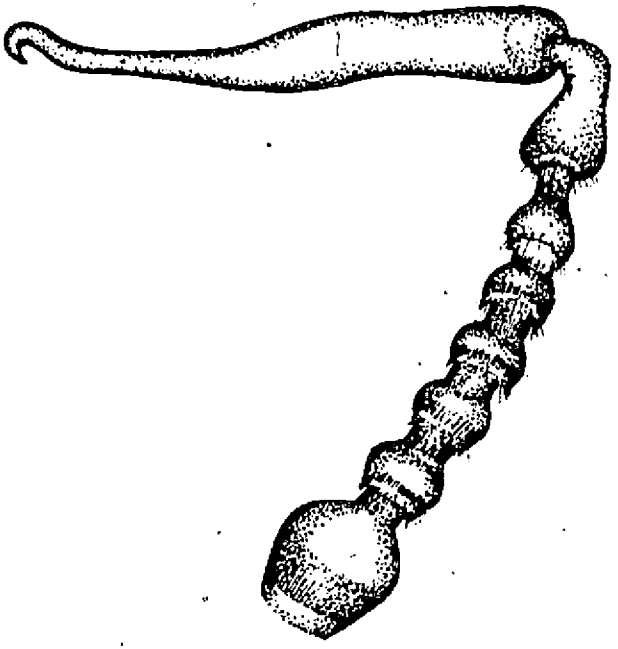
1. Scape

2. Funiculus

3. Club



A. antenna



B. antenna

4.3.4.2.1. Legs

The mean total length of the first, second and third pairs of legs were 7.53, 6.6, 7.96 mm in the male and 8.81, 8.17 and 9.76 mm in the female weevils respectively (Table 6, Fig. 5 & 6, Plate 7a & b). Generally, the coxae were large and strongly globose. Fore, mid and hind coxae were measured to be respectively 0.79, 0.80, 0.86 mm long in the male and 1.07, 1.05, 1.17 mm in the female and were therefore, apparently sub-equal in each sex. Trochanter was short and triangular in all the pairs of legs in both sexes. The measurement of the femora of the three pairs of legs in both male and female sexes were respectively as follows, hind femur (2.98, 3.17) mid femur (2.295, 2.37) and fore femur (2.68, 2.53) cm. These results showed that hind femur was the largest and mid femur was the smallest one in both sexes.

Tibia was long and slender with slightly bulged mid portion in all the pairs of legs. The apex of the tibia was expanded and having a fine spine like projection (Fig. 5 & 6). The respective length of fore, mid and hind tibiae were 2.25, 1.79 and 2.27 mm in male and 2.54, 1.97 and 2.32 mm in female (Table 6).

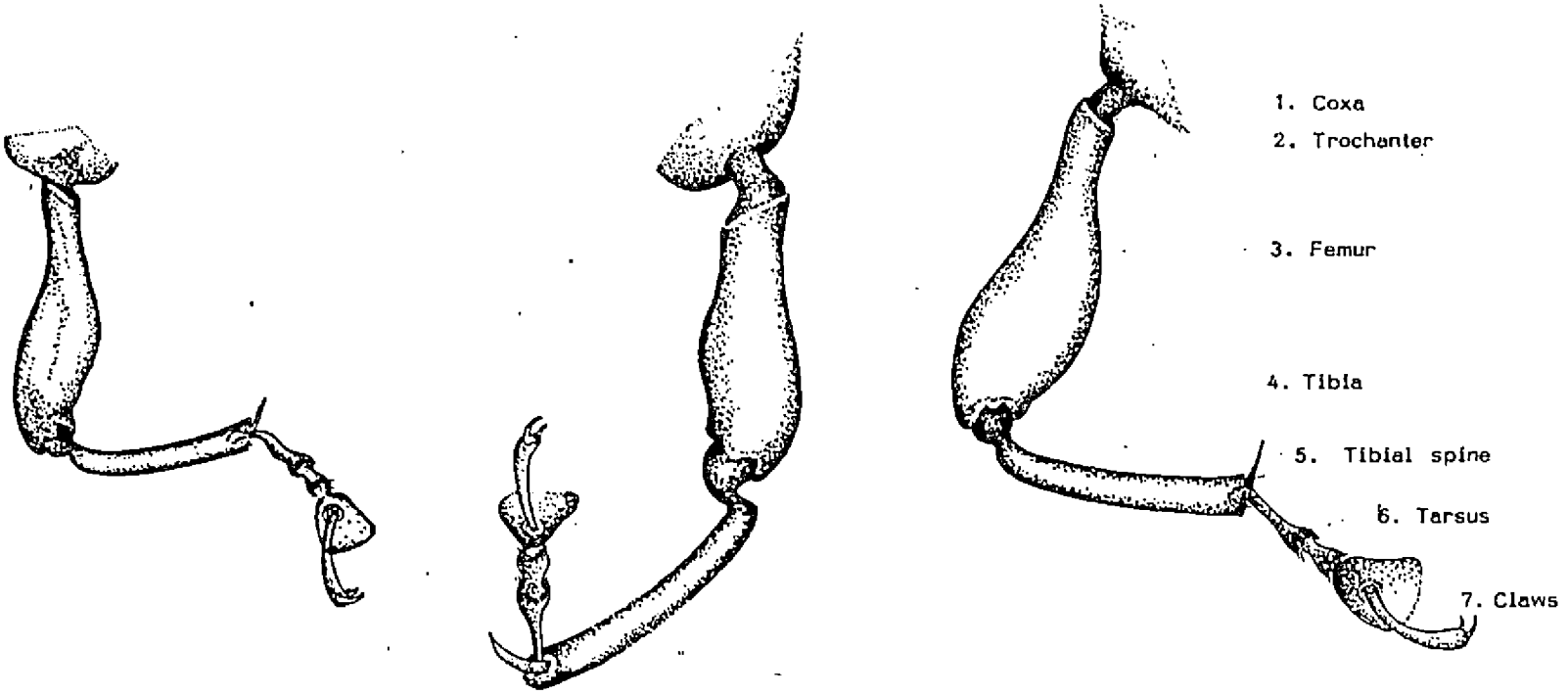
Tarsi were short having three segments. The first segment was larger than the second and the third being strongly bilobed and much larger than the others. The claws were having almost

Table 6 . Morphometrics of the thoracic legs of O. longicollis*

Thoracic legs		Length(L)/ width (W)	Measurement (mm)				(t, table value 2.101) calculated t value
			Male		Female		
			Range	Mean	Range	Mean	
a. Length (Total Length)							
	Fore leg		6.42-8.35	7.53	7.6-9.8	8.81	-22.88
	Mid "	L	6.25-7.40	6.60	7.6-8.9	8.17	0.64
	Hind "		7.05-8.85	7.965	9.0-10.9	9.76	0.408
b. Coxa							
	Fore "		0.65-0.85	0.785	1.0-1.1	1.07	0.23
	Mid "	L	0.65-1.0	0.80	1.0-1.2	1.05	1.92
	Hind "		0.75-1.0	0.855	1.0-1.5	1.17	0.66
c. Femur							
	Fore "		2.5-2.75	2.68	2.0-3.0	2.53	0.14
	Mid "	L	2.10-2.70	2.29	2.1-2.8	2.37	0.07
	Hind "		2.5-3.5	2.98	2.8-3.5	3.17	0.13
d. Tibia							
	Fore "		2.25-2.75	2.25	2.1-2.5	2.54	0.25
	Mid "	L	1.55-2.0	1.79	1.9-2.2	1.97	0.19
	Hind "		2.0-2.5	2.26	2.2-2.6	2.32	0.05
e. Tarsus							
	Fore "		1.5-2.0	1.82	2.1-3.2	2.67	0.79
	Mid "	L	1.5-2.0	1.71	2.6-2.9	2.78	1.02
	Hind "		1.5-2.0	1.865	2.4-3.9	3.10	1.04

* Average of 10 replicates

Fig. 5 . Legs of O. longicollis ♂



A. Pro thoracic leg

B. Meso thoracic leg

C. Meta thoracic leg

Plate 7. Legs of O. longicollis

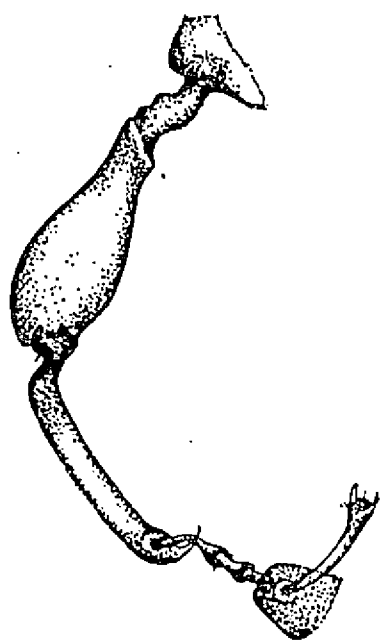
a. ♂ weevil

b. ♀ weevil

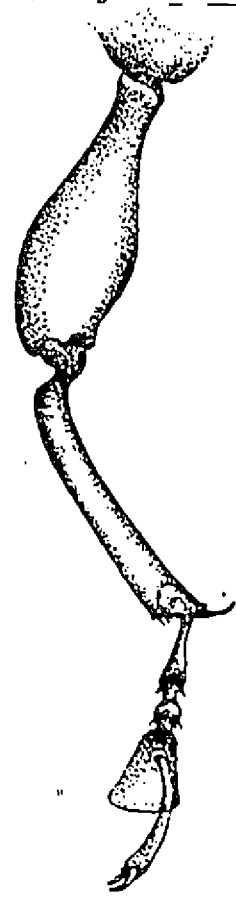
a

b

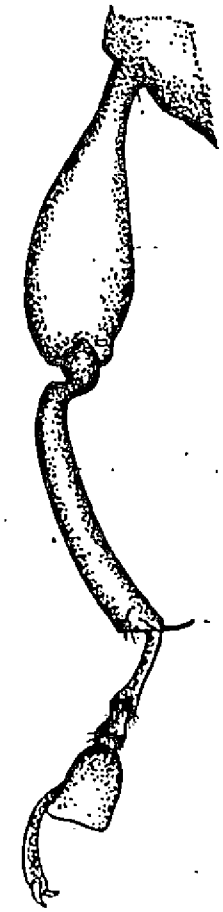
Fig. 6. Legs of O. longicollis ♀



A. Pro thoracic leg



B. Meso thoracic leg



1. Coxa
2. Trochanter
3. Femur
4. Tibia
5. Tibial spine
6. Tarsus
7. Claws

C. Meta thoracic leg

the same length in all the three pairs of legs in both the male and female weevils.

4.3.4.2.2. Wings

The elytra were convex and heavily chitinsed and were wider than prothoracic region (Plate 8.a and Fig. 7). The size of the elytron of the male in terms of its length and breadth (6.57 x 2.74 mm) was significantly smaller than that of the female (6.92 x 3.16 mm) and showed a clear size difference between the sexes (Table 5). The proportional size of the elytron in the case of male was 2.4 times as long as wide, while, the same in the case of female was 2.2 times only. The dorsal side of the elytron showed 10 rows of linearly arranged punctuations organised in a beaded manner. The number of these linear markings was reduced to nine towards the hinder half of the elytron.

The hind wings were elongate, membraneous and broad basally. Most of the veins were atrophied and venation, therefore indistinct (Plate 8.b,Fig. 7). The hind wing was folded transversely as well as longitudinally so that, they could be accomodated beneath the elytron. This transverse fold necessitated a modification of the venation and as a result, there was a discontinuity between the proximal and distal parts of the veins. The distal end of the wing folded longitudinally first and transverselly twice. The second transverse fold was at the middle region of the wing. Jugal fold was also present.

Plate 8. Wings of *O. longicollis*

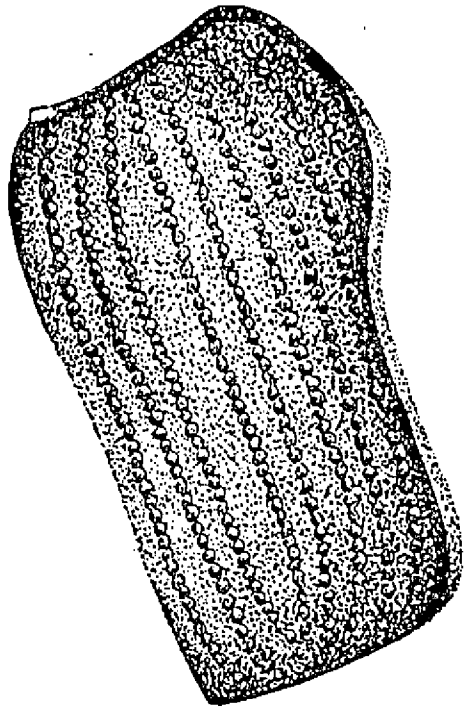
a. Elytron

b. Hind wing

a

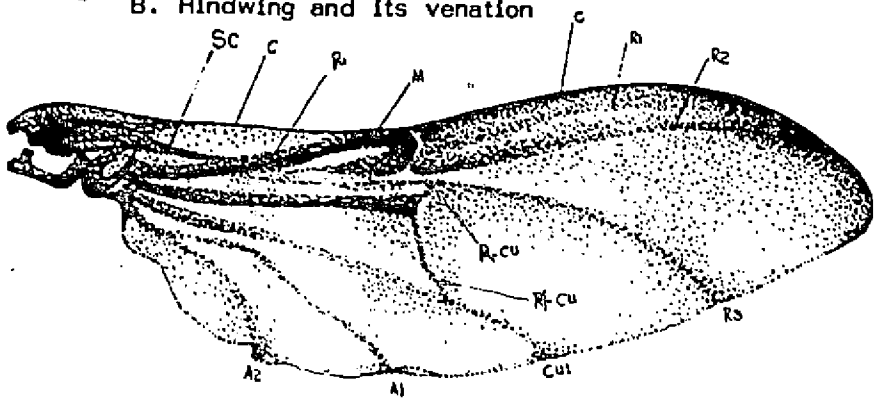
b

Fig. 7 . Wings of O. longicollis



A. Elytron

B. Hindwing and its venation



Sc - Subcosta
C - Costa
R - Radius
M - Median
R_1 - Radial 1
R_2 - Radial 2
R_3 - Radial 3
M-cu - Medio cubitus
R-cu - Radio cubitus
Cu_1 - Cubital vein 1
A_1 - Anal vein 1
A_2 -Anal vein 2

Female had larger hind wing (14 x 4 mm) than that of the males (14 x 3 mm). However, the hind wing of the female was 3.5 times as long as wide while, in the male it was 4.6 times as long as wide. The venation of hind wing is a modification of cantharoid type. The detailed pattern of the venation of the hind wing was depicted as in Fig.7.

4.3.4.2.3. Abdomen

The abdominal region comprising of 6 segments tapered towards the anal end with a downward curve and with the three distal abdominal segments exposed and naked extending beyond the elytra. The dorsum covering the exposed three abdominal segments unite to form an anal plate like structure; which lacked the normal pigmentation and hence with an offwhite colour. The tip of the abdomen, comprising of the last three segments were relatively narrower than that of the females. But the absence of any external genitalia on the abdominal tip as well as the absence of any marked difference in the shape and size of these region make the sex determination based on the abdominal characters difficult.

4.3.4.3. Sex determination by a statistical procedure

As per 3.3.3.1. Ten specimens each of the confirmed sexes of both male and female were subjected to morphometric observations and the characters were grouped and classified according to their relative importance (Tables 7 and 8).

An insect was separately collected at random from the field and all its body measurements were taken. These measurements were then grouped according to the various criteria fixed for the determination of the sex. The first group of measurements for the determination of sex was found to be 0.672, 0.67, 1.42, 0.192 and 0.22 mm with respect to As, Rl, Rw, Hcl and Hcw respectively. The criteria derived were 0.75, 0.5, 4, 1.68 and 1.15 mm respectively for the same. As, all the values fell below the criteria level, the sex of the insect was confirmed as male. This judgement was further confirmed with an expert opinion on sex, showing that the criteria selected were the most suitable and easy determinant for the determination of sex. Eventhough, the sex was confirmed with the first set of criteria itself, as a matter of illustration, the confirmatory criteria were also matched, which would further confirm the determination. For example, a weevil collected from the field was recorded to be having its morphometric observations taken in the same sequential order as 0.5, 0.5, 4, 1.9 and 1.25mm with respect to As, Rl, Rw, Hcl and Hcw respectively. On comparison with the derived criteria, all the measurements, except that of the position of the antennal socket (As) were at par or subequal with the criteria derived. Since the measurement of the position of the antennal socket (As) was of much importance, the confirmatory criteria was also taken into consideration before the final judgement. The confirmatory criteria measurement for this insect was recorded to be 5.45, 3.87, 8.6 and 5.37 mm with respect to Tl, Tw, Al

Table 7. Morphometric measurements in descending order of importance and criteria derived

	Male					Female				
	(As	Rl	Rw	Hcl	Hcw)*	(As	Rl	Rw	Hcl	Hcw)*
1)	(0.75,	0.45,	3.6,	1.75,	1)	(0.35,	0.50,	4.50,	1.60,	1.25)
2)	(0.70,	0.50,	4.0,	1.60,	1)	(0.45,	0.60,	4.30,	1.85,	1.25)
3)	(1.0,	0.50,	4.0,	1.55,	1.15)	(0.50,	0.45,	3.50,	1.45,	1.15)
4)	(0.75,	0.50,	3.75,	1.65,	1.25)	(0.75,	0.50,	4.25,	1.60,	1.25)
5)	(0.75,	0.45,	3.85,	1.50,	1.05)	(0.60,	0.50,	4.10,	1.50,	1.25)
6)	(0.75,	0.50,	3.75,	1.55,	1.0)	(0.50,	0.60,	4.50,	1.75,	1.35)
7)	(0.70,	0.50,	3.95,	1.65,	1.0)	(0.55,	0.50,	4.25,	1.65,	1.25)
8)	(0.85,	0.50,	3.75,	1.65,	1.0)	(0.50,	0.45,	4.50,	1.80,	1.15)
9)	(0.75,	0.50,	3.85,	1.60,	1.05)	(0.70,	0.50,	4.50,	1.75,	1.25)
10)	(0.80,	0.45,	3.90,	1.50,	1.0)	(0.50,	0.50,	4.0,	1.80,	1.15)

Derived criteria : (0.75, 0.5, 4, 1.68, 1.15)

*As - Position of the antennal socket
Rl - Rostral length
Rw - Rostral width
Hcl - Head capsule length
Hcw - Head capsule width

Table 8 . Morphometric measurements in descending order of importance and criteria derived

	Male (Tl Tw Al Aw)*	Female (Tl Tw Al Aw)*
1)	(5.2, 4.0, 7.7, 5.0)	(5.6, 3.8, 9.1, 5.3)
2)	(5.0, 4.2, 7.5, 5.3)	(4.8, 2.2, 8.0, 4.7)
3)	(5.0, 4.0, 7.9, 5.8)	(4.0, 3.5, 8.6, 5.0)
4)	(5.0, 4.8, 8.0, 5.2)	(4.8, 4.0, 7.3, 5.3)
5)	(5.0, 4.0, 9.0, 5.2)	(4.7, 3.4, 9.1, 4.0)
6)	(4.9, 3.9, 8.0, 5.2)	(4.7, 4.1, 8.5, 5.2)
7)	(5.0, 3.6, 8.0, 5.3)	(5.7, 4.1, 9.5, 5.1)
8)	(5.0, 3.9, 8.2, 5.2)	(5.3, 3.8, 8.5, 5.3)
9)	(5.0, 4.0, 8.3, 5.0)	(5.0, 3.7, 8.7, 4.5)
10)	(4.5, 3.5, 7.8, 5.5)	(5.0, 4.0, 8.9, 4.4)

Derived criteria: (5.3, 3.85, 8.55, 5.25)

*Tl - Thoracic length
Tw - Thoracic width
Al - Abdominal length
Aw - Abdominal width

and Aw. The derived confirmatory criteria with respect to the above morphometric characters were 5.3, 3.85, 8.55 and 5.25 mm respectively. From the above data, the sex of the weevil could be determined as a female.

However, there might be chances of minor variations with respect to the first set of criteria and the confirmatory criteria derived. The probable reason for the same might be ascribed to the seasonal influence, the ecotypic variation and also due to the nutritive support obtained for the different weevil generations as influenced by the host plant reactions.

4.4. Preliminary control measures against the weevil infestation

4.4.1. Preventive protection with natural products

Commercially available natural products namely neem oil and fish oil insecticide soap (FOIS) were selected because of their availability, cheapness and non-hazardous nature. These were applied at the standard recommended dosages to ascertain any feeding or oviposition deterrant action against the weevil and also to find out their prolonged efficacy on the highly waxed plant surface. The commercially available synthetic sticker (Sandovit) at one per cent level was added to break the hydrophobic action of the wax coating and thereby increasing the tenacity and penetration of these natural products on the plant surface. After spray with the natural products, observations on the weevil damage conducted at monthly

intervals till harvest showed that the treated plants were relatively unifested. But the results were inconclusive as the farmer was adopting an intensive insecticidal application to protect his Nendran crop which led to a less field population of the pest in the area.

4.4.2. Curative protection

4.4.2.1. Padding technique

The observational trial with padding technique with dichlorvos insecticide indicated adult and grub mortality of the weevil in and around the tunnels and riddles within the plant tissue. In both varieties tested, namely Palayankodan and Nendran under both flowering and pre-flowering stages, it was observed on the 7th day that the presence of the insect stages was adversely affected with the insecticide padding technique. This technique, therefore, could be tried to salvage plants with early to moderate level of infestation, provided, the attack was already detected. Being a less residual fumigant insecticide, it might not result in undesirable terminal residues in the plantain fruits. The padding technique with dichlorvos insecticide would not cause any health hazards as experienced with the aluminium phosphide tablets fumigation. The efficacy of Aluminium phosphide as an effective fumigant against the weevil as reported by Dutt and Maiti (1972) could not be widely recommended because of its immediate and dangerous reaction with the watery surfaces causing so much human health hazards.

4.4.2.2. Injection technique through pseudostem, rhizome and root portions

4.4.2.2.1. Pseudostem injection

The systemic insecticide, monocrotophos was coupled with two per cent Rhodamine Bdye and tracked the movement of the insecticide within the plant tissues to ascertain their acropetal and basipetal translocation. The insecticide administered through the bore holes of size 0.5 cm diameter and 5 cm depth was found to be holding 5 ml of the proprietory insecticide-dye mixture. The 45° angle at which the bore holes were made facilitated the holding of the insecticide without any spillage and exposed the maximum number of leafsheaths for translocation. From the experiment, it was observed that the movement of the insecticide was following a very narrow linear path and finally spread and covered a very limited portion of the pseudostem only as evidenced by the streaks produced by the dye. So, the lateral diffusion of the insecticide was very limited and therefore, more number of bore holes were required to get a complete coverage within the affected tissues. Therefore, this method would damage the pseudostem portion and invite further decay and infestation. Further, the turgor pressure exerted by the root absorption of fluids resulted in the spillage and wastage of the chemical. Therefore, it was not a feasible technique against the weevil as a curative measure.

4.4.2.2.2. Rhizome injection

In order to administer the systemic insecticide, monocrotophos, by this injection technique, rhizomes had to be exposed and bore holes to be made with a cork screw borer. Bore holes of size 3 cm in length and 0.5 cm in diameter was made and the insecticide-dye mixture was injected through a 5 ml pipette. There was practically very little absorption, even when the insecticide-dye mixture was poured in the bore hole and sealed with plaster of paris. Therefore, higher volume of the insecticide-dye mixture was administered through a 20 ml pipette, retaining the same in the bore hole for 3 days. After 3 days, when the rhizomes were cut and examined, there was negligible absorption and lateral spread. From the above observation it could be concluded that the technique was not satisfactory.

4.4.2.2.3. Root feeding

As the rhizome injection was unsatisfactory and defective, root feeding was tried as an observation. From this experiment it was found that all the roots absorbed the material, though, the rate of absorption through the excised roots was faster than through roots with rootcaps. But the practical disadvantage observed was that the insecticide absorbed moved as a very narrow streak through the conducting vessel with practically no lateral diffusion. The dye streak exhibited on the pseudostem emanating

from a single feeding root was found to be finally terminating as a very limited portion of the leaf lamina only. Therefore, it might be concluded that to make this root feeding effective, we have to administer as many roots as possible which again suggested that the method was quite impracticable at field level as a curative method.

4.4.3. Biological control

4.4.3.1. Lab studies

The nematode culture was prepared and stocked as described in 3.4.4.1. Instar variation of the grubs were determined based on the body length, width and weight of the grubs (Table 9). The first instar grubs were selected which were having an average body length of 2-6 mm and an average body weight of 10-100 mg. The second instar grubs had a range of 6-10 mm in length and body weight of 100-200 mg. The body length ranged from 10-14 mm and body weight 200-300 mg in the case of third instar grubs. And in the case of fourth instar it was 12.5-15 mm in length and 300-400 mg in weight, respectively. The measurement range of fifth instar grubs was 15-20 mm in length and 400-500 mg in body weight. Accordingly, all the five instars of the grub stages were sorted out and inoculated with the nematode suspension at three inoculum loads viz., 50, 100, 500 nemas/g body weight. Under each set, five grubs were tested. The observations on the grub mortality

Table 9. *In vitro* mortality of *O. longicollis* grubs due to the parasitic nematode (*Steinernema* sp.) infection

Treatment	Grub instars	Length (mm)	Weight (mg)	Inoculum load (N/ml)	No. of grubs incubated	No. of grubs dead	% mortality
T_0 (c)*	Ist	5-6	12-77	0	3	3	0
T_1		2-3	5-12	50	5	5	100
T_2		3-4	25-35	100	5	5	100
T_3		4-5	50-80	500	5	5	100
T_0 (c)	2nd	9-10	100-200	0	3	3	0
T_1		6-7	100-125	50	5	5	100
T_2		7-8	125-160	100	5	5	100
T_3		8-9	160-200	500	5	5	100
T_0 (c)	3rd	13-14	200-300	0	3	3	0
T_1		10-11	200-225	50	5	5	100
T_2		11-12	230-260	100	5	5	100
T_3		12-13	270-300	500	5	5	100
T_0 (c)	4th	14-15	300-450	0	3	3	0
T_1		12.5-13	300-320	50	5	5	100
T_2		13.5-14	325-350	100	5	5	100
T_3		14-15	350-450	500	5	5	100
T_0 (c)	5th	18-20	450-600	0	3	3	0
T_1		15-16	450-520	50	5	5	100
T_2		16-17	525-580	100	5	5	100
T_3		17-18	590-625	500	5	5	100

* T_0 (c) - Control
T_1 - 10 nemas/ml
T_2 - 100 nemas/ml
T_3 - 500 nemas/ml

were recorded at 24 hours interval. All the grubs were dead within ten days after inoculation. All the five instar grubs recorded complete mortality with the cadavers (except in the control) showing symptoms typical to neoaplectanid infection. All such infected cadavers were removed to the collecting dish for the re-extraction of nematode.

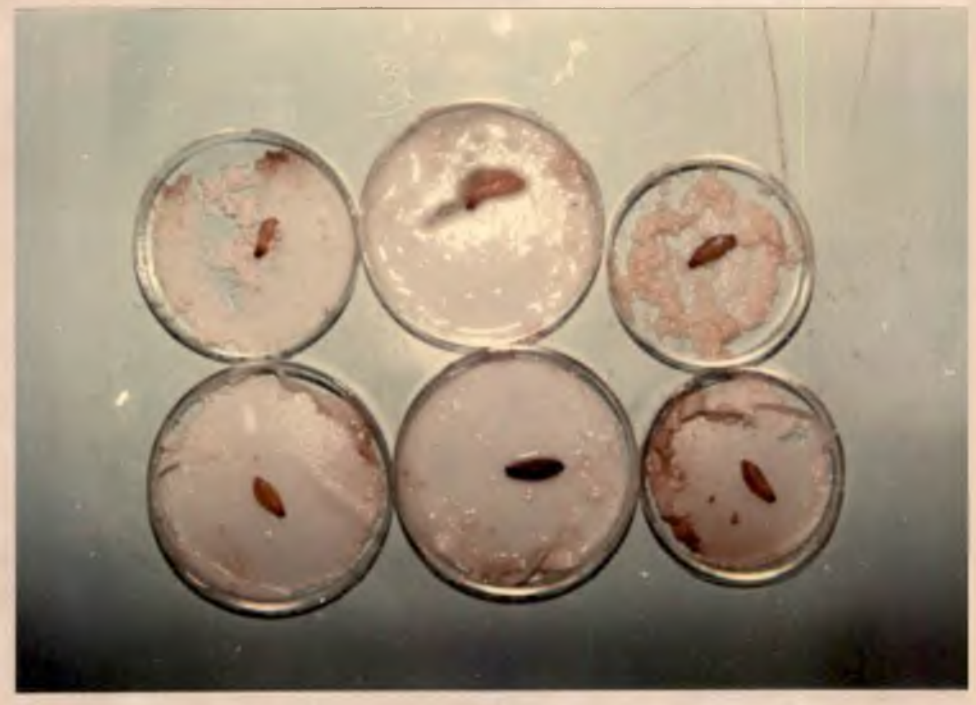
All the cadavers were then subjected to the re-isolation process as given in 3.4.4.1. to confirm that the mortality was caused by nematode infection or not. From the cadavers of the first and second instar grubs and their respective control grubs, it was not possible to re-extract the nematode juveniles which suggested that their mortality was not due to the nematode infection. Thereby, it could be inferred that the above instars are not preferred by the juvenile parasitic nematode or rather they are tolerant to the parasitic nematodes. In contrast, the cadavers of the third, fourth and fifth instar grubs gave varying levels of nematode counts per unit volume of the extract. The number of juvenile nematodes per 0.1 ml of the extract were counted to be 300, 450-500 and 800-1600 nemas respectively from the third, fourth and fifth instar grubs (Plate 9a, b, c).

This, has revealed that the advanced stages of the grub instars were more susceptible to the nematode infection progressing with the age of the instars. This might be due to the increased

Plate 9. *In vivo* mortality of *O. longicollis*, grubs by the parasitic nematode, *Steinernema* sp. (DD-136)

a. III instar grubs

b. IV instar grubs



c. V instar grubs

size of the body openings viz., at the buccal, anal and spiracular regions through which the parasitic nematodes penetrate into the host body. It also confirmed that practically there was no cutaneous penetration of the nematode. Therefore, the biological control method utilizing this parasitic nematode could be developed as a curative method against the weevil attack provided, the susceptible stage of the host, an effective nematode culture formulation and a suitable method of application were available.

4.4.3.2. Field studies

In all the examined plants, under each variety and stage of flowering, none of the stage/stages of the grubs were found to be affected. This showed that, the parasitic nematodes were either ineffective or incapacitated to cause any mortality of the grub stages within the plant tissues as against the in vitro performance. The possible reasons for the ineffective performance of these nematodes might be the following: (1) Disorientated method of application, (2) The relative tolerance or susceptibility of different instars of the grub and (3) The hostile conditions within the plant and its possible role in reducing the virulence of the nematode larvae for movement and penetration into the host tissues. As it was a very preliminary observation, the exact reason for the nematode inactivity and the rectification of the method for nematode inoculation could not be further investigated.

Summary

SUMMARY

Experiments were conducted at the College of Horticulture, Vellanikkara and in the farmers field at Kainthikara, Alwaye during 1989-1990 to investigate upon the symptoms and nature of attack, biology, morphology and preliminary control measures of the banana pseudostem weevil, Odoiporus longicollis Oliv.

The results of the study are summarised below.

a. Symptoms and nature of attack:

1. Under field conditions, the banana plants were generally observed to be getting infested from the fourth month onwards after planting coinciding with the peduncle formation. Externally the early symptoms of attack were not visible except for the small oviposition holes/punctures made by the adult weevil on the outer sheaths. The grubs emerged from the eggs deposited singly within the air chambers of the leaf sheath started feeding immediately on the parenchymatous tissues and bored into the inner sheaths causing extensive internal riddles and tunnels. The bore holes exhibited gum exudation in the initial stage of attack on young plants. The tunnelling extended both towards the base as well as towards the distal end of the plant from the point of entry and thereby weakening the pseudostem portions. During the later stages of attack all the tissues were damaged by the grubs within the tunnels which as a result got decomposed and resulted in the total collapse of the pseudostems. In the case of young plants, delayed flower emergence resulted in the

formation of undersized bunches. Badly damaged plants break at the weaker portions of the pseudostem or snap at the stool even in mild winds leading to complete crop loss.

2. Under green house conditions, it was found that, apart from the above mentioned symptoms, the grubs bored through the leaf petioles showing excessive gummosis which got collected in the leaf whorls especially in young and susceptible varieties.

b. Biology

1. Eggs were laid singly within the air chambers by the female weevil through the oviposition slits cut with the rostral beak on the outer epidermel layer of the leaf sheath. The mean incubation period was 2.3 days with a mean hatchability of 90 percentage.

2. The larvae were apodous soft and fleshy and bored into the pseudostems voraciously feeding on the parenchymatous tissues. There were five distinct larval instars which lasted for 2-3, 4-7, 4-6, 5-7 and 6-8 days respectively during I to V instars. The fifth instar was the longest in duration which included the pre-pupal stage also, while, the fourth instar was the most voracious feeder.

3. The cocoon was made by cutting small pieces of fibres from the hard and fibrous regions of the leafsheath. The cocoon was located at the end of the larval tunnels invariably towards

the periphery of the pseudostem. It was found to be positioned along the axis of the leafsheath but never across it. The pupal period including the pre-emergence resting period lasted for 11.2 days on an average.

4. The adults immediately on emergence were brownish and later turning to brownish-black to black in colour. The emerged adults were negatively photrophic preferring a dark and humid condition. Therefore, the adult weevils hide during day time and could be trapped effectively. The adult longevity under captive feeding was 170 days, while, under starvation it survived only for 1-2 weeks. It showed the importance of crop fallowing and field sanitation to reduce the carryover of the pest infestation.

5. The adult weevil pair effected multiple mating throughout day and night. The pre-ovipositional period was 15.5 days after effective mating and the oviposition continued till death.

6. The mean number of eggs laid by the female with a single mating was 9 eggs at the rate of one egg per day.

c. Morphology and Morphometrics

1. Eggs were smooth, offwhite in colour and more or less cylindrical in shape with rounded ends having a prominent air space at the anterior region. The mean length and width of the egg were 2 and 1 mm respectively.

2. The mean body length and width of the 1st, 2nd, 3rd, 4th and 5th instar larvae were 3.75 and 1.32, 6.25 and 1.75, 12.57 and 2.78, 13.38 and 3.38 and 18.41 and 4.95 mm respectively.

Kaya, H.K., J.L. Jos, L.A. Falcon and A. Berlowitz. 1984. Suppression of the codling moth (Lepidoptera:Olethrecutidae) with the entomogenous nematode, Steinernema feltiae (Rhabditida: Steinernematidae). J. Econ. Ent., 77:1240-1244.

*Kung, K.S. 1955. The banana stem borer weevil Odoiporus longicollis Oliv. in Taiwan. J. Agric. for. Taiwan. 4:80-113.

*Kung, K.U.S. 1964. Ecological studies on banana stem borer weevil Odoiporus longicollis Oliv. J. Agric. for Taiwan, 11:137-160.

Luo, L.Y., Q.C. Luo, X. Yao and Z.L. Liu. 1985. Weevils injurious to banana in Guizhou (China) and their biological features. Insect knowledge, 22(6):265-267.

Madhu, S. 1989. Control of cashew stem borer, Plocaederues ferrugineus L. by the DD-136 nematode (Neoaplectana carpocapsae Weiser. 1955. M.Sc. Thesis submitted Kerala Agricultural University, Trichur. 100pp.

Marshall, G.A.K. 1916. The fauna of British India including Ceylon and Burma. Coleoptera:Curculionidae Rhynchophora. Today and Tomarrows Printers and Publishers, New Delhi. pp.16.

Mc Swiney, J. 1920. Report of the Agrl. Dept. Assam, for the year ending 31st March 1920, Shillong. pp.6-7.

Muir, F. and O.H. Swezey. 1916. The cane borer beetle in Hawai and its control by natural enemies. Rept. Hawaiian sugar planters' Assoc. Expt. Sta., Honolulu, Ent. Bull. 13:102.

Pinto, M.P.D. 1928. The weevil pests of plantains (Musa sapientum), Odoiporus longicollis Oliv. Trop. Agriculturist, IXX(4):216-224.

3. The pupal cocoon was having a mean length of 32.2 mm and a width of 12.73 mm and the naked pupa without its cocoon was having a mean length of 15.2 mm and a width of 10.34 mm.

4. The mean length and width of the male and female weevils were 15 and 5 mm, and 19 and 5.2 mm respectively. Females were invariably found larger than the males in all sets of morphological characters. The number of punctuations on the rostral surface were more and were more pronounced in the case of males, giving the rostral surface a rough appearance as compared to the relatively smooth surface of the same in the female weevils. This was the most distinguishingly apparent character between the two sexes. The attachment position of the antennae on the rostrum was measured to be 0.78 mm away from the base of the rostrum in the male and 0.54 mm in the female weevils. Morphometric observation between the two sexes showed a clear sexual dimorphism which were, however, apparently not visible externally and had no practical value in determining the sex. However, the more pronounced character of the rostral punctuations and the relative size and shape of the rostrum as well as the relative position of the attachment of antenna could be considered for the sex determination. The external colour could not be taken as a character for determining the sex as reported and claimed elsewhere.

d. Preliminary control measures

1. Preliminary control measures were tested mainly in the farmers field at Kainthikkara, Alwaye. The prophylactic protection with the fish oil insecticide soap (FOIS), neem oil emulsion and neem kernel suspension gave inconclusive results with respect to any oviposition deterrence or antifeedent property against the weevil. The treated plants were found to be relatively uninfested as compared to unsprayed plants in the field.

2. Padding technique with dichlorvos as a curative measure resulted in the adult weevil mortality in and around the bore tunnels. The technique, therefore, could be used on the plants with early to moderate level of infestations.

3. The injection technique tried through the pseudostem, rhizome and root portions with the insecticide-dye mixture was found to be an ineffective method as the insecticide showed very little acropetal and basipetal translocation with no apparent lateral diffusion.

4. The feasibility of the parasitic nematode, DD-136, Steinernema feltiae (= Neoaplectana carpocapsae) as a biological control agent against the O. longicollis showed in vitro mortality of the 3rd, 4th and 5th instar grubs within 10 days after inoculation under laboratory conditions. The lowest dose of 50 nemas per ml of the nematode suspension was as good as that of the highest dose

of 500 nemas per ml. Among the different instars, it was found that the 5th instar grubs were the most susceptible stage as evidenced by the maximum number of juvenile nematodes (800-1600 nemas per 0.1 ml extract) reisolated from the parasitised cadaver followed by the 4th and 3rd instar grubs.

5. Bio-efficacy of the nematodes under field conditions against the weevil infestation in banana, gave no satisfactory results probably due to the improper method of administration, stage suitability of the grubs and the hostile plant conditions.

References

REFERENCES

Batra, H.N. 1952. Occurrence of 3 banana pests at Delhi. Indian J. Ent. 14:60.

Bedding, R.A. 1984. Nematode parasites of Hymnoptera. (In) Plant and Insect Nematodes. ed. Nichle, W.R., Marcel Dekker Inc., New York. pp.756-795.

*Blinova, S.L. and E.S. Ivanov. 1980. Culturing the nematode bacterial complex of Neoaplectana carpocapsae. (In) Gelminty Nasekomykh, Nauka, Moscow. pp.13-20.

*Chiang, J.J.H. 1965. Studies on the inheritable variability of radiation of insects and the biological control of sterilized insects. J. Agric. For Taichung., 14:255-269.

*Danilov, L.G. 1980. Aspects of penetration and subsequent development of Neoaplectana carpocapsae strain "Agriotos" in insects during free contact between the parasite and the host. Nauka., 42-46.

Dias, S.J.F. 1935. Report on the work of the division of plant pest control. Adm. Rep. Dir. Agric. Ceylon, pp.60-66.

*Dutky, S.R., J.V. Thompson and G.E. Cantwell. 1964. A technique for the mass propagation of the DD-136 nematode. J. Insect. Pathol., 6:417.

Dutt, N. and B.B. Maiti. 1973. Bionomics of the banana pseudostem weevil Odoiporus longicollis Oliv. (Coleoptera:Curculionidae)., Indian J. Ent., 32:20-30.

Edward, J.C., S.C. Tripathi and K.P. Singh. 1973. Observations on a tip over disease of banana in Allahabad. Curr. Sci., **42**(19):696-697.

Fletcher, T.B. 1914. Report of the Imperial Entomologist. Rept. Agric. Res. Inst. & Coll. Pusa. Calcutta: 62-75.

Fletcher, T.B. 1916. Agricultural Entomology Reprint from Ann. Rept. Bd. Scientific Advice for India 1914-1915. Calcutta Economic Zoology:1-15.

*Frogatt, J.L. 1928. The banana weevil borer in Java with notes on other crop pests. Queensland Agric. J., XXX:530-591.

Gaugler, R. 1981. Biological control potential of neoaplectanid nematodes. J. Nematol., **13**(3):241-249.

Gupta, S.R. 1927. Entomology Rep. Dept. Agric. Assam, 1926-27: 31-32.

Hoffmann, W.E. 1932. Observations on a weevil injurious to Banana. Hongkong Nat., IV(1):48-54.

Hutson, J.C. 1921. Report of the Entomologist Ceylon. Dept. Agric. Rep. pp.15-16.

Hutson, J.C. and C.C. Ghosh. 1922. Report of the Entomologist, Ceylon. Dept. Agric. Rep. pp.23-26.

Isahaque, N.M.M. 1978. A note on the incidence of Odoiporus longicollis Olivier on banana in Assam, Pesticides, **12**(6):22-24.

Jepson, F.P. 1934. Report on work of division of plant pest control. Adm. Rep. Div. Agric. Ceylon. pp.104-124.

Kaya, H.K., J.L. Jos, L.A. Falcon and A. Berlowitz. 1984. Suppression of the codling moth (Lepidoptera:Olethrecutidae) with the entomogenous nematode, Steinernema feltiae (Rhabditida: Steinernematidae). J. Econ. Ent., 77:1240-1244.

*Kung, K.S. 1955. The banana stem borer weevil Odoiporus longicollis Oliv. in Taiwan. J. Agric. for. Taiwan. 4:80-113.

*Kung, K.U.S. 1964. Ecological studies on banana stem borer weevil Odoiporus longicollis Oliv. J. Agric. for Taiwan, 11:137-160.

Luo, L.Y., Q.C. Luo, X. Yao and Z.L. Liu. 1985. Weevils injurious to banana in Guizhou (China) and their biological features. Insect knowledge, 22(6):265-267.

Madhu, S. 1989. Control of cashew stem borer, Plocaederues ferrugineus L. by the DD-136 nematode (Neoaplectana carpocapsae Weiser. 1955. M.Sc. Thesis submitted Kerala Agricultural University, Trichur. 100pp.

Marshall, G.A.K. 1916. The fauna of British India including Ceylon and Burma. Coleoptera:Curculionidae Rhynchophora. Today and Tomarrows Printers and Publishers, New Delhi. pp.16.

Mc Swiney, J. 1920. Report of the Agrl. Dept. Assam, for the year ending 31st March 1920, Shillong. pp.6-7.

Muir, F. and O.H. Swezey. 1916. The cane borer beetle in Hawai and its control by natural enemies. Rept. Hawaiian sugar planters' Assoc. Expt. Sta., Honolulu, Ent. Bull. 13:102.

Pinto, M.P.D. 1928. The weevil pests of plantains (Musa sapientum), Odoiporus longicollis Oliv. Trop. Agriculturist, IXX(4):216-224.

Poinar, G.O. 1971. Use of nematodes for microbial control of Insects. (In) Microbial control of Insects and Mites. (eds) Burges, H.D. and N.W. Hussey. Academic Press, New York. pp.181-203.

Poinar, G.O. 1979. Nematodes for Biological control of Insects. CRC Press, Boca Raton, Florida.

Poinar, G.O.Jr. and G.M. Thomas. 1967. The nature of Achromobacter nematophilus as an insect pathogen. J. Invertebr. Pathol., 9:510.

Rao, D.R. 1983. Statistical technique in Agricultural and Biological research. Oxford and IBH Publishing Company, New Delhi, Calcutta. pp.24-38.

*Schmiege, C.D. 1964. A note on taxonomy of an underscribed insect parasitic nematode in the Genus. Neoaplectana Parasitology, 54:233-236.

Shukla, G.S. and K. Kumar. 1969. A new record of Odoiporous longicollis Oliv. (Coleoptera:Curculionidae) from Uttar Pradesh. Sci. and Cult., 35:481-482.

Shukla, G.S. and A.K. Tripathi. 1978. Effect of temperature on longevity of Odoiporus longicollis Olivier (Coleoptera:Curculionidae). Ent. News, 89(9/10):249.

Singh, S.S. 1966. Observations on Odoiporus longicollis on banana in Katmandu valley and its suburbs. Indian J. Ent., 28(37):410.

Speyer, E.R. 1918. Report on the work of the Entomological division. Ceylon Adm. Rept. for (1971) Dept. Agric., Feb. 1918.

*Stanuzek, S. 1974. Neoaplectana feltiae complex (Nematoda:Rhabditoidea, Steinernematidae) its taxonomic position within the genus Neoaplectana and intraspecific structure. Zesz. Probl. Postepow Nauk. Rolh. **154**:331.

Triggani, O. and G.O. Poinar. 1976. Infection of adult lepidoptera by Neoaplectana carpocapsae (Nematode). J. Invertbr. Pathol. 56:427.

Tripathi, A.K. and M.L. Chaturvedi. 1978. Adult Odoiporus longicollis (Coleoptera:Curculionidae) feeds on own larvae. Entomological News **89**(3/4):88.

*Uichanco. 1936. Miscellaneous notes on Locusts, Agriculture and people in Mindanao. Phillipp. Agric., **25**(7):365-588.

*Weiser, J. 1954. Neoaplectana carpocapsae n. sp. (Anguillulata: Steinernematinae) novy cizopasnik hoaxnek obaleec jabelecneho, Carpocapsae pomonella L. Veslin cesk., Spol. Zool., **19**:44.

Wouts, W.M. 1984. Nematode parasites of lepidopterans. (In) Plant and insect nematodes. (ed) Nickle, W.R., Marcel Dekker Inc. New York. pp.655-699.

* Originals not seen

BIOLOGY OF BANANA PSEUDOSTEM WEEVIL

Odoiporus longicollis Oliv.

(COLEOPTERA : CURCULIONIDAE)

By

JAYASREE, T. V.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur
Kerala

1992

ABSTRACT

The Banana Pseudostem Weevil, Odoiporus longicollis Oliv., considered as one of the destructive pests in North and North-East India is very recently found to be causing wide spread damage in the banana growing tracts of Ernakulam and Trissur districts of Kerala. The present investigation was envisaged to properly understand about the nature of attack, symptomatology, bio-ecology, morphology and the preliminary control measures of the pest species under both field and laboratory conditions.

The insect pest is associated with the banana plants throughout the year in Kerala in overlapping generations with its maximum population during both the monsoon periods. This insect has a very congenial condition in Kerala for their survival and multiplication in general and its hot spots of infestation were identified to be around Alwaye-Perumbavoor regions in Ernakulam District.

Of late, the infestation was observed to be spreading to other Districts also. The banana varieties more susceptible to its attack were found to be Nendran, Palayankodan and Poovan, while, Njalipoovan was relatively tolerant.

The adult weevils preferred to oviposit on the outersheaths on 3-4 months old plants coinciding with the peduncle formation at a height ranging from 3-4 meter above ground level. The weevil

grubs bored into the pseudostem portions and cause extensive tunnelling and riddling leading to weakening of growth, delayed flower emergence, smalling of bunches and finally breakage and lodging leading to partial or complete loss of the crop.

The biology, morphology and biomorphometrics of the insect under laboratory conditions were worked out in detail.

Because of the peculiar nature of the plant and the fruit produce, as well as the type and nature of the pest species, chemical means of control by spray impregnation of natural products, injection of systemic insecticide through root, rhizome and pseudostem portions and padding technique with fumigant insecticide gave inconclusive results. Bio-control with the parasitic nematode, DD-136, Steinernema sp., eventhough showed good in vitro mortality under lab conditions, it was not successful under field condition.

From the above studies, it was found that, to contain the pseudostem weevil infestation effectively, an integrated pest management strategy with special emphasis on cultural techniques on a community basis should be evolved and practiced.