

**STUDIES ON THE BIOLOGY, VARIETAL RESPONSE AND CONTROL OF  
BANANA RHIZOME WEEVIL, *COSMOPOLITES SORDIDUS* (GERMAR)  
(COLEOPTERA : CURCULIONIDAE)**

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BANGALORE

**1976**

STUDY ON THE BIOLOGY, HABITAT RESPONSE AND CONTROL OF  
BY JAWA RAJ SOMI WEVIL (COLLEOPTERA: CURCULIONIDAE)  
(GERMAN)

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STUDIES ON THE BIOLOGY, VARIETAL RESPONSE AND CONTROL OF  
BANANA RHIZOME WEEVIL, COSMOPOLITES SORDIDUS (GERMAR)  
(COLEOPTERA : CURCULIONIDAE)

BY

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THESIS

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY  
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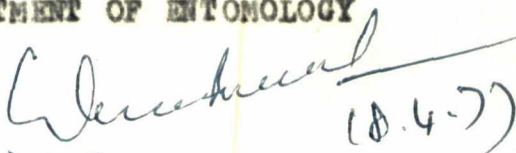
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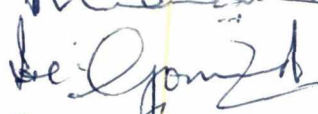
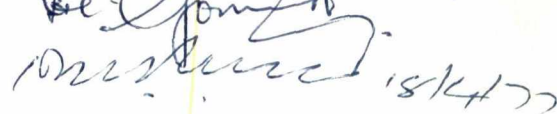
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# *INTRODUCTION*

## I. INTRODUCTION

India is believed to be the original home of banana (Musa paradisiaca Linn.), the Queen of tropical fruits.

Banana is grown under a variety of climatic conditions, wet tropical to dry sub-tropical. In India banana is not only grown as a main crop, but also grown as a subsidiary mixed crop along with certain plantation crops.

It is grown over an area of about two lakh hectares constituting about 14 per cent of the total area under fruits in the country. Among banana producers, India occupies the second place in the world.

Banana is considered merely as a fruit in the Western countries. But in India, especially in South India it is put to diverse utility. The green or unripe fruit, the central axis of the pseudostem and even the rhizome are cooked and eaten with other food. Unripe fruits are dried and powdered for use as balanced food for babies and are also used for making banana chips. The ripe banana fruit may be eaten fresh or can be dried and preserved, and it provides very suitable form of carbohydrates. In the Indian system of honouring or greeting each other, the fruit is invariably offered as a sign of mutual helpfulness.

Of the several insects reported on this crop, the rhizome weevil, Cosmopolites sordidus (Germar) is a cosmopolitan and destructive pest inflicting damage every year. In some countries the pest has assumed major threat to the cultivation and large scale production of banana. Many countries like Australia, Jamaica and U.S.A. have quarantine laws prohibiting the movement of suckers and other parts of the crop to confine the spread of the pest.

Very little is known about the biology of this pest in India and particularly in Karnataka. A knowledge of its biology and behaviour is an essential prerequisite for a rational approach in the control of this insect. A study on this aspect of the weevil was undertaken at the Agricultural College, Hebbal, Bangalore. In addition, studies on its distribution in Karnataka, varietal resistance and chemical control of this weevil were also covered in the present investigation. The results obtained are presented in the following pages.

*REVIEW OF LITERATURE*

## II. REVIEW OF LITERATURE

Cosmopolites sordidus (Germer) has been reported as a serious pest of banana from many countries. The species was first described as Calandra sordida from 'India orientali' by Germer (1824). He described the species as follows : Elytra with striae mostly well impressed and some intervals appearing elevated; most intervals on dorsum in part distinctly raised and polished (Polished areas bare of pruinosity) especially basal, and the elytra (in clear specimens) distinctly vittate.

Later the name was changed very frequently. Zimmerman (1942) confirmed and stated C. sordidus as the valid name of this insect. Following is the list of names used by workers for C. sordidus.

Calandra sordida (Germer, 1824)

Sphenophorus striatus (Fahraeus, 1845)

S. cribricollis (Walker, 1859)

Cosmopolites sordidus (Chevrolot, 1835)

Four synonyms were given by Fletiauss and Salle' (1889) for C. sordidus :

- C. striatus Fahrs
- C. crenatus Sturm
- C. javanus Weterman
- C. pygidialis Chev. (doubtfully)

Csiki (1936) in his coleopterous catalogues listed Curculio mendicus Olivier as a synonym of C. sordidus. But this surely seems to be an error, and it would appear from Olivier's figure that the species did not even belong to the subfamily calandrinae (Zimmerman, 1968a).

Systematic position :

C. sordidus is now included under the family curculionidae, subfamily rhynchophorinae (Zimmerman, 1968a). He further reported another species C. pruinus (1968c).

Geographical distribution :

C. sordidus is a native of Asia but has been widely distributed on cultivated bananas of the world. Its centre of origin is probably the Malaya-Java-Borneo region (Simmonds, 1966).

According to Zimmerman (1968a), C. sordidus is evidently of Indo-Malayan origin. C. sordidus is widely

spread all over the banana growing countries of the world. The broad regions are included in Table I.

Economic status of the pest :

The weevil has been reported as a serious pest of banana from many countries. The number of prohibitory and quarantine laws passed against this pest emphasise the importance of this pest (Anonymous, 1916a,b, 1919).

The entry of leaves and shoots of banana from Jamaica to Cuba was prohibited on account of C. sordidus (Anonymous, 1919). The United States of America has prohibited entry of any species of Musa except for scientific purposes (Moznette, 1920). Under the plant protection ordinance No. 10 of 1924 of Ceylon, C. sordidus on bananas was declared as pest. Proclamation under the plant diseases act 1924 of New South Wales prohibited introduction of banana, plantain or manila hemp plant parts except under permit on account of C. sordidus. An order under legislative and administrative measures of Spain, prohibited (except under permit) the introduction of plants or plant parts of the genus Musa from any place into Canary Islands to avoid introduction of banana weevil, C. sordidus (Anonymous, 1934). Quarantine measures were undertaken against C. sordidus in Australia (Anonymous, 1935).

Table I  
Distribution of C. sordidus in the world

Countries/localities	Source
Brazil, Java, Ceylon, Malacca, Saigon, China.	Chevrolat, 1885
Ceylon, Java, Borneo, NewGuinea, Malacca, Saigon, China, Fiji, West Indies, Madagascar, Reunion, Brazil, Sikkim, North Bengal, Peru, Tenaserrium, Andamen Islands, Sambak and Seychellus.	Jepson, 1914
Jamaica, Guadeloupe, Dominica, Martinique and Trinidad in West Indies, Brazil in South America, The Philippines, Fiji, Borneo, Sumatra, India, Queensland and the Straits of settlement in east.	Ballou, 1916
Fiji, British West Guinea, Jamaica, India and Brazil.	Pierce, 1917
Guadeloupe, Martinique, Dominica, Trinidad, Brazil, Costa Rica, Philippines, Fiji, Borneo, Sumatra, India, Straits of settlements and Queensland.	Watts, 1917

Contd. Table I

Countries/localities	Source
Lower Congo, Madagascar, Mauritius, Seychellus, Ceylon, India, Malay States, Saigon, China, Java, Sumatra, Borneo, New Guinea, Fiji, Brazil, Trinidad, West Indies and Florida.	McCarthy, 1920
Andamans, Borneo, Brazil, Burma, Ceylon, China, Costa Rica, Dominica, Fiji, Florida, Guadeloupe, India, Jamaica, Java, Lower Congo, Madagascar, Malacca, Malay States, Martinique, New South Wales, Queensland, Papua, Peru, Philippines, Rarotonga, Reunion, Seychellus, Singapore, Sunda Islands St. Lucia, Tenasserim, Trinidad and Uganda.	Jardine, 1924
China, Indochina, Malaya, Java, Ceylon, Queensland, Brazil, Islands of Pacific and Indian Oceans, Central Africa, Central America, West Indies, Since 1920 it has spread into almost all other banana- growing regions except into Egypt, Isreal and Hawaii. It is now effectively Pan-tropical and its distribution is South East Asia generally, Eastern Australia and West Australia, The Pacific, generally Islands (except Hawaii) in the Indian	Simmonds, 1966

Contd. Table I

Countries/localities	Source
ocean, Tropical and South Africa, Tropical America, from Southern U.S.A., to Southern Brazil.	
North, Central and South America, Medeira, Africa, and South Asia and is widely dispersed through the islands of the tropical pacific.	Anonymous, 1968 Zimmerman, 1968a,b
<u>In India</u>	
Malabar, Coimbatore, Godavari and Ganjam in South India and Western India, as far North as Poona	Fletcher, 1914 1917
Delhi	Batra, 1952
Andhra Pradesh, Assam, Bihar, Gujarat, Kerala, Madras, Maharashtra, Mysore, Orissa, Uttar Pradesh, West Bengal.	Anonymous, 1963
In Karnataka - Srirangapatna, Hesseraghatta etc.	Usman and Puttarudriah, 1955

Mackie (1917) in his report mentioned the insect as the cause of death of a large number of abaca and banana plants in Paete, Laguna Province, when abaca industry was partially ruined. Edwards (1936) stated that banana plants were blown down by high winds due to the infestation by C. sordidus in Jamaica. In Japan (Shiraki and Sonan, 1937), C. sordidus has spread over the whole island of Taihoku causing enormous damage. It was reported to have destroyed bananas on a small island in South of Lake Victoria (Harris, 1943).

According to Roy and Sharma (1952) the weevil damaged 8 to 10 per cent of the plants in Sabour, India. The weevil was wide spread with an infestation averaging 82.61 per cent and 2.84 per cent in Central and South Formosa respectively (Cheng, 1957). The annual loss caused by banana weevil probably amounted to many thousand pounds in Fiji (Fawcett, 1913).

Nature of damage and symptoms :

Many workers have reported the nature of damage caused by this pest. According to Froggatt (1919), the newly hatched larvae burrowed downwards, as they fed and grew, into the base of the stem, packing the tunnels they excavated with the gnawed tissue behind them. The bulb of

the infested plants was found to be riddled and tunnelled, which was characteristic of the weevil (Fawcett, 1913; Jepson, 1914; Moznette, 1920; Cendana, 1922). The noticeable damage was that the rounded bores running through the healthy white tissue. If the larvae were numerous, the whole of the basal portion of the stem became a spongy or felted mass of tissue (Pinto, 1928; Harris, 1947; Braithwaite, 1963; Gaud, et al., 1975).

Cendana (1922) stated that the newly hatched grub ate its way down the sheath and tunnelled inwards and downwards until it reached the young fleshy part of the bulb where it remained for sometime. Then it tunnelled its way horizontally, later slightly upwards to the growing point of the sucker (Fletcher, 1914). Here it travelled up and down tunnelling the sucker as high as 25 cm above the surface of the ground. Tunnelling extended from 12" (McCarthy, 1920) upto two to four feet (Froggatt, 1925; Roy and Sharma, 1952) and even to several feet (Braithwaite, 1963; Feakin, 1971). In banana plants bearing fruits, which were seriously affected, the fruits failed to develop to their normal size and fullness (McCarthy, 1920; Cendana, 1922; Sen and Prasad 1953; Gaud, et al., 1975) and flower clusters when developed were abnormally small (Cendana, 1922).

According to Fawcett (1913), young suckers attacked by the borer with-ered and died quickly. The first indication that a sucker was attacked, was the death of young leaves while still unrolled (Jepson, 1914; Cendana, 1922; Gaud. et al., 1975). Due to the damage the normal supply of food to the plant was obstructed and growth of the suckers was arrested, causing the leaves to die prematurely, finally the roll of unopened leaves or the growing point of the plant to wither (McCarthy, 1920; Gaud. et al., 1975).

Froggatt's observations (1923b,c) showed that the grub tunnelled through the outer portion of the bulb, and in this process some of the roots were either cut off at the base or damaged which caused the death of the whole root. The effect was two fold: firstly the plant lost a certain amount of food through loss of roots and had to use reserve stores to send out fresh ones; secondly, when this dying back of root occurred the plants did not have enough support in the ground and fell down (Froggatt, 1925; Roy and Sharma, 1952; Gaud. et al., 1975). Then the grub entered the heart of the bulb, where it destroyed a large amount of tissue, thus decreasing the food storage capacity. Subsequently, decay set in along these tunnels, further destroying the bulb. This resulted in reducing the vitality and yield of the plant.

More than half the damage done by larvae was confined to the outer edge of the bulb, and since this was the zone within which many of the vascular bundles that convey nourishment to the growing parts of the plants are located it is clear that the damage done was more than mere removal of a certain amount of plant tissue (Knowles, 1919). The injuries also encouraged the growth of fungus and bacterial diseases which soon reduced the whole bulb into a blackened mass of decaying tissue. In this condition it was deserted entirely by the beetle larvae (McCarthy, 1920).

In the case of attack of banana, plantain and abaca (Musa textiles), it induced loss of vigour, chlorosis, and atrophy of the terminal shoots and the roots (Swain, 1952). Further, the larval tunnels facilitated the entry of the disease organisms, which would kill the plants subsequently.

Feakin (1971) reported that the damage caused by the weevil was often increased by other insects and bacteria, and severe attack frequently developed when plantations were weakened through drought or other adverse factors. The initiating cause might be drought which was followed by weevil attack and subsequently bacterial attack. Attacked plants were more easily blown down. Infested rhizomes were so weak that a mere touch would push them over (McCarthy 1920; Cendana, 1922; Braithwaite, 1963; Hill, 1975) or break

at the ring tunnel (Froggatt, 1921) or snap and breakdown at the place of infestation when there was a strong blast of wind (Batra, 1952; Sen and Prasad, 1953).

In older suckers the only sign outwardly noticeable was the loss of vigour in the stools. The attack did not kill but only weakened them (Cendana, 1922) and reduced the vitality and resistance to drought (Harris, 1947).

According to Roy and Sharma (1952), fruited plants fell down having broken at one to two feet above ground level. Sometimes plants were left with vigour sufficient to develop only a few hands. In badly infested plantations poor and weedy suckers came out and seriously affected plantations (Harris, 1947; Sen and Prasad, 1953).

Simmonds (1966) stated that damage done by weevil was primarily the result of destruction of tissue of the corm, and young seedlings might be killed if the larvae attacked the young growing point. According to Fletcher (1914), a number of grubs occurred in one root-stock which was tunnelled through-out. The attack was usually confined to root-stock (Subramanian, 1936).

Froggatt (1923a) was of the view that the damage caused to a sucker even by a single larva might be sufficient to kill the plant. But d'Emmerez (1921) felt that

the attack by large number of grubs was required to cause the death.

Peyronnet (1931) stated that the presence of banana borer C. sordidus which was very prevalent in abaca might be detected by alkaline sap or pith of the plant (healthy plants have acid sap or pith).

Hosts :

According to published records, Cosmopolites sordidus apparently confined itself entirely to banana, attacking all varieties (Moznette, 1920). However, McCarthy (1920) reported the record of this pest on sugar-cane by Newell. But Gendana (1922) working on this insect found no basis for this claim either from his own observation or in literature.

Different species under the genus Musa are attacked: Musa textiles (Mackie, 1917; Uichanco, 1936; Sen and Prasad, 1953; Gallego, 1956), Musa fehi (a local variety of Tahiti) (Lever, 1944; Millard, 1952) and Musa martinii (Bruner, 1945).

C. sordidus was more serious as a pest of plantain than of banana (Wolcott, 1934). Stray instances of attack on potato tubers, arrow root (Canna edulis Edw.) (Froggatt, 1925), Yam and rhizomes of Guinea grass (Wolcott, 1922) have

been observed.

External morphology of the stages :

Egg : Egg is elongate oval, white in colour (Moznette, 1920; Froggatt, 1925; Sen and Prasad, 1953; Braithwaite, 1963; Hill, 1975), rounded at one end and more or less pointed at the other (Jardine, 1924), pale yellow in colour (Tryon and Benson, 1920).

As the eggs develop, the apical ends gradually become hyaline for about one third of their length. The basal ends also become hyaline for a short time, the former then turns cloudy (Froggatt, 1923c) and twentyfour hours before the larva is ready to emerge, the jaws appear as two fine brown lines, then the palpi are seen, later plates of the head. This gradual development is visible through the egg envelope (Froggatt, 1923c).

Egg measures 1.33 to 2.11 mm long (Tryon and Benson, 1920; Froggatt, 1925) and 0.6 to 0.845 mm broad (Tryon and Benson, 1920; Pinto, 1928).

Grub :

Freshly emerged grub is 2 mm long (Gendana, 1920), 1/2" (2.1 mm) long whitish except head which is brown

(Pinto, 1928). Fully grown grub is fleshy, legless, cream (Fawcett, 1913; Fletcher, 1914) with middle portion presenting a swollen appearance, the head is reddish brown (McCarthy, 1920; Jardine, 1924; Harris, 1947; Roy and Sharma, 1952; Braithwaite, 1963; Peakin, 1971). Head light orange with narrow, short, non pigmented stripes dorsally, free, longer than broad, the sides subparallel, rounded posteriorly. Endocarina present, one third to one half as long as frons (Anderson, 1948), head is squarish when viewed anteriorly (Whalley, 1958). Epicranial suture marked black on its posterior half and ~~white~~ white thence forward to the frons (Moznette, 1920).

On the epicranium a pair of light lines depart from the frontal sutures and passed backwards almost as far as the light median line of epicranium, corresponding to adfrontal sutures which sometimes occur in Rhynchophora. Each lobe of epicranium bears setae as follows: One at each terminus of the rudimentary adfrontal sutures; a small one opposite the middle of the frontal sutures; a long hair opposite the basal one third of the frontal suture; one - opposite the middle of pleurostoma; one near the hypostomal angle of the mandible; one opposite the basal third of hypostoma; one on disk behind this; Four tiny ones on the disk near the basal angle of the lobe (Moznette, 1920).

Antennae fleshy, two-jointed, located at the lateral angle of the frons. First joint broad and short, bears one or more tiny hairs, second joint slender, finger like, but short (Moznette, 1920).

Frons subtriangular, emarginate at anterior angles for antennae and emarginate along epistoma for attachment of clypeus. The median line is faintly indicated by a dark line in the basal half (Moznette, 1920). Frons with four pairs of setae, two pairs small, two pairs long, the three posterior pairs, the last of which is smallest, though the first is also small, form a triangle, first and last almost equidistant. Anterior pair large and attached to the basal angles of clypeus and some little distance from the antennal fossae (Moznette, 1920). Frons with five pairs of setae (Zimmerman, 1968a). Frontal setae 4 short to very short, seta 5 long (Anderson, 1948). Clypeus attached in front of frons, basally marginated with dark brown, otherwise light in colour, bears four tiny hairs on epistomal margin (Moznette, 1920). Anterior margin of labrum pointed, ventral side of labrum humped posteriorly (Whalley, 1958). Labrum with one basal sensillum, labral seta two branched, labral rods united posteriorly (Anderson, 1948). Labrum not so broad, rounded in front, has a row of four setae in front of the middle, and is marginated with setae (Moznette, 1920).

Epipharynx with the antero-lateral and two pairs of antero-median setae branched (Anderson, 1948). Labrum with twelve marginal thickened setae (Cotton, 1924). All setae on anterior margin of labrum many branched (Whalley, 1958; Cotton, 1924). Asperities on epipharynx moderately conspicuous laterally and between the labral rods, in evident tufts about the base of all anterior setae (Anderson, 1948). Epipharynx setose with two pairs of thickened setae between the epipharyngeal rods (Cotton, 1924).

Mandibles dark brown, bidentate with median and basal hairs (Moznette, 1920; McCarthy, 1920).

Maxillae elongate, terminated by a two jointed palpus and a setose lecinia. They are provided with two setae near palpus and one near base (Moznette, 1920). Maxillary mala oval at tip, with a row of nine branched setae on dorsal surface and with one branched and two simple setae at tip (Cotton, 1924). Mala with asperities on dorsal surface along the line of setae. Mala with five ventral and ten dorsal setae, the posterior seta on ventral surface and nine posterior setae on dorsal surface branched (Anderson, 1948). Setae on dorsal side of mala many branched (Whalley, 1958).

The stipes labii triangular, cordate, rather acutely

angulate at base, bearing two jointed palpi at basal angles with discal pair of setae and with several pairs of basal setae (Moznette, 1920). Posterior margin of labium pointed (Whalley, 1958). Ligula not produced without asperities (Anderson, 1948); ligula with two somewhat triangular setose areas on dorsal surface (Cotton, 1924). Posterior pair of setae on postmentum separated by less than  $1/2$  the distance separating the middle pair of setae (Zimmerman, 1968a).

The body glabrous except for the usual hairs found on each segment (Moznette, 1920), on head, thorax and terminal segments (Pinto, 1928). Body is naked with upper surface wrinkled and segmented divisions of the body showing more distinctly on the under surface (McCarthy, 1920). Thoracic segment constricted to form a neck between it and the swollen abdominal segments which swell out in the centre and are contracted at the anal extremity (Froggatt, 1919). The three thoracic segments are rather more developed than the abdominal ones (McCarthy, 1920).

There are six pairs of setae on prothorax the last of which occur on the alar lobe. Behind these on the scutal area are four pairs of hairs, the last of which occur on the alar lobe (Moznette, 1920); alar area with one very short seta (Anderson, 1948).

Mesothoracic spiracle elongate with longitudinal slit, occur on a large lobe which causes an emargination of the prothorax and lies very close to the head (Moznette, 1920), thoracic spiracle elongate, curved (Zimmerman, 1968; McCarthy, 1920).

Meso and metathoracic segments dorsally consist of a spindle shaped prescutum with a single pair of setae and the scutellum extending between alar lobes and bearing only two pairs of hairs in the region of the alar lobe. The epipleurum of the mesothorax and metathorax bears a single hair. Each hypopleural lobe bears two setae. Each thoracic sternum bears one pair of hairs and each parasternum bears three pairs of hairs (Moznette, 1920). Seta on epipleurum of metathorax distinctly shorter than the seta on epipleurum of mesothorax (Anderson, 1948; Zimmerman, 1968a). The seta on pleurum of mesothorax and metathorax long (Anderson, 1948). Spiracular area of mesothorax with one very short seta (Anderson, 1948).

The first seven abdominal segments normal (Moznette, 1920; McCarthy, 1920). Segments grow larger to the fourth or fifth segment which are the largest and then decrease in size (Moznette, 1920; McCarthy, 1920), seventh is the smallest of normal segments (Moznette, 1920). Larvae moderately large, slightly thicker through IV, V and VI (Anderson,

1948). This gives the whole body of the larva a swollen appearance (McCarthy 1920). Abdomen with posterior end abruptly truncate (Whalley, 1957). Abdomen not tapering gradually, fifth segment abruptly scooped out (Whalley, 1958).

The first seven abdominal segments bear a minute spiracle (Moznette, 1920; McCarthy, 1920; Anderson, 1948; Zimmerman, 1968a). The first seven spiracles rudimentary and not easily visible (Whalley, 1958).

Each abdominal prescutum bears one pair of setae and each scutellum bears a small lateral pair. Each epipleural lobe bears two pairs of setae, each hypopleural lobe is apparently longitudinally divided into two parts, the lower of which bears a single seta (Moznette, 1920), typical abdominal segments with three post dorsal setae (Anderson, 1948; Zimmerman, 1968a). Setae of spiracular area very short (Anderson, 1948). No setae on the sternum of the abdomen (Moznette, 1920).

Eighth segment dorsally greatly modified with a single pair of hairs on the prescutum and a single pair on the scutellar area and with elongated spiracle, just outside of the spiracles on the epipleural lobe are two strong setae (Moznette, 1920).

The dorsal face of eighth segment is declivous, the

dorsum of the ninth segment is flattened and bears four pairs of setae. The dorsum of ninth segment extends underneath, so that it is apical to the entire tenth segment. The tenth segment is completely ventral and very small (Moznette, 1920), caudal (9th) abdominal segment without fleshy processes (Zimmerman, 1968a). Asperities inconspicuous, sparsely distributed dorsally and ventrally on abdominal segments III to V. Posterior margin of abdominal segment IX without projections (Anderson, 1948). The anal segment has a depression above and a pair of elongate oval spiracles with scattered hairs below (Froggatt, 1919).

Full grown grub is about 13 mm (Moznette, 1920), 20 mm (Fawcett, 1913) in length and 8 mm in width (Fawcett, 1913), 1/3" (8.46 mm) broad (Pinto, 1928) and 5 mm in diameter (Cendana, 1922).

#### Prepupa :

Body becomes flaccid and elongated with the thoracic segments more prominent (Froggatt, 1922, 1925; Roy and Sharma, 1952).

#### Pupa :

Pupa naked (Moznette, 1920; Tryon and Benson, 1920), white or pale yellowish white (Tryon and Benson, 1920;

Moznette, 1920; Jardine, 1924; Feakin, 1971).

Calandrid in form (Moznette, 1920) with the structure of the future beetle plainly visible, the rostrum, antennae, wingpads, and legs all prominent (McCarthy, 1920). Possessing very large spiracles located on a prominent lobe at the base of the prothorax (Moznette, 1920; McCarthy, 1920). Beak irregularly margined with numerous depressions (Moznette, 1920). Snout turned down in front of the head. Two rows of short tubercles on the head and snout (Froggatt, 1919). Four pairs of large tubercles set with setae one on head and three on beak and two pairs of tiny setae located medially to the two basal pairs on the beak (Moznette, 1920).

Prothorax elongate, subquadrate, rounded in front, with basal angles rounded (Moznette, 1920), bears six pairs of setigerous tubercles (Moznette, 1920; McCarthy, 1920), of which apical pair longest. There are two anterolateral and one anteromedian pairs of setae. Mesothorax has one pair of scutellar setae (Moznette, 1920).

The first six abdominal segments normal (Moznette, 1920; McCarthy, 1920), each bears three pairs of scutellar setae (Moznette, 1920), bears three pairs of bristles on tubercles which are placed so close together as to form

a ridge-like prominence on either edge of the dorsal surface (McCarthy, 1920). A row of rounded spiracles on the sides of the abdomen (Froggatt, 1919). Spiracles are larger and more prominent than the larval spiracles (Moznette, 1920; McCarthy, 1920). Seventh and eighth spiracles minutes (Moznette, 1920). Rest of the segments greatly modified (i.e. VII, VIII, IX and X) (Moznette, 1920; McCarthy, 1920). Dorsally seventh is elongate (Moznette, 1920; McCarthy, 1920), apically tuberculate (Moznette, 1920), has two pairs of setigerous tubercles (Moznette, 1920; McCarthy, 1920), one pair being on the larger apical tubercle (Moznette, 1920).

From a lateral view it is seen that the seventh segment is dorsally the terminal segment, but ventrally it is emarginated for the reception of the other segments (Moznette, 1920; McCarthy, 1920). The ninth is set with two long chitinous processes (Moznette, 1920; McCarthy, 1920), at the side of which are two setigerous tubercles (Moznette, 1920), a pair of stiff spines (McCarthy, 1920). Last abdominal segment with one large and two fine ventral spines on each side, dorsal side of last abdominal segment with 4 papillae, each bearing a spine, (Whalley, 1958). Pupa with one pair of ventral spines on last abdominal segment, thick and larger than all the others (Whalley, 1957). Anal segment with stout yellowish spine on either side of preceding

segment (Froggatt, 1919).

Pupa is 0.5 inch (12.7 mm) in length (Tryon and Benson, 1920; Hill, 1975), 12 mm long (Moznette, 1920) and 0.2 inch (5.8 mm) broad (Pinto, 1928).

Adult :

Freshly emerged weevil is soft and brown, gradually skin hardens and almost becomes black (McCarthy, 1920; Harris, 1947; Simmonds, 1966), it takes 14 to 15 days, often longer to become fully coloured (Froggatt, 1923c). Adult is dark brown to black in colour (Jardine, 1924; Froggatt, 1925). Body is covered with a thin encrustation when dried, which gives it a greyish appearance (McCarthy, 1920), it is black (Chestnut brown when young), dull having a thin greyish surface encrustation, when abraded, otherwise glossy (Tryon and Benson, 1920), with a long slightly curved trunk in front of the head and has numerous punctures or small depressions along the back (Jardine, 1924; Froggatt, 1925). Head small, spherical (Moznette, 1920; McCarthy, 1920), sinks in the midbody to the middle of the eyes and has a long, narrow downwardly curved beak or proboscis (Tryon and Benson, 1920; McCarthy, 1920). Beak separated from head by constriction, swollen in basal one third, finely punctate in basal half, moderately curved, slender and cylindrical and smooth

in apical half. Scrobes located in basal one third beneath the swelling, oval more approximated behind the front (Moznette, 1920). Beak moderately turned downwards, thickened between antennae, with mouthparts situated at apex (McCarthy, 1920). Antennae elbowed (Tryon and Benson, 1920; McCarthy, 1920), geniculate (Moznette, 1920). Scape almost as long as funicle, six jointed, first joint moniliform, succeeding joints more closely appressed, last joint very closely appressed to club. Club two jointed, basal joint occupying two thirds of length, shining, with a few minute hairs, apical joint spongy, short and rounded at apex. Other funicular joints having a few tiny hairs (Moznette, 1920). Eyes finely granulate, elongate, oval, transversely contiguous beneath, anteriorly margined (Moznette, 1920).

Prothorax long, moderately evenly punctate, with an irregular smooth median line indicated on disk; narrowest at apex (Moznette, 1920; McCarthy, 1920), constricted near apex; apex tubular; roundingly broadening to about the middle; sides almost parallel from middle (Moznette, 1920). Thorax is covered with fine punctures and the elytra are straightened longitudinally and also finely punctured (Froggatt, 1925; Roy and Sharma, 1952). The wing covers or elytra have impressed lines of striae containing rows of punctures (McCarthy, 1920; Froggatt, 1919). Striae moderately impressed,

punctate, intervals of irregular width, the first, third and fifth being slightly wider than the alternate intervals, minutely punctate (Moznette, 1920). Elytra with numerous low ribs, each separated by narrow furrows (Punctured striae) (Tryon and Benson, 1920). Elytra stop short of the abdominal end (Froggatt, 1925; Roy and Sharma, 1952; McCarthy, 1920) freely exposing the pygidium (McCarthy, 1920) which is pubescent and covered with setigerous punctures (Moznette, 1920; McCarthy, 1920), underside more sparsely punctate (Moznette, 1920). Hind wings membranous, folded beneath the elytra, well developed, greatly exceeding elytra in size and length (Tryon and Benson, 1920). Body divisions head, thorax and abdomen distinct (McCarthy, 1920).

Adult weevil thickly covered (except on the dorsal surface of thorax and wing covers) with a fine greyish buff pubescence. The head, rostrum (except the lower portion), the whole of thorax, legs and undersurface of the body thickly and finely punctured. The wing covers finely impressed with parallel lines forming regular bars, between which they bear fine punctures. The bottom of the furrowed lines are also punctured, but more coarsely, particularly along the outer margin of wings (Froggatt, 1919). The mid body bowed on each side is covered above by numerous minute points (Tryon and Benson, 1920).

First two abdominal segments connate at middle. Third and fourth segments about as long as second. Fifth segment longer and turned downward (Moznette, 1920).

Legs stout (McCarthy, 1920; Tryon and Benson, 1920), procoxae and mesocoxae cylindrical, metacoxae oval, trochanter small, femora laterally compressed and curved, ventrally inflated at middle, emarginate beyond this and bilobed at apex, thus forming a groove for tibiae (Moznette, 1920), femora thickened at the distal end (McCarthy, 1920). Tibiae moderately straight, grooved beneath and provided with a row of setae on each side of the groove, apically curved downwards (Moznette, 1920), terminating in a strong hook (Moznette, 1920; McCarthy, 1920). Tarsi 4-jointed (Moznette, 1920; McCarthy, 1920), first longer than broad, widest at apex, second as long as broad, third about as long as first but broader at apex, emarginate for reception of fourth. Fourth elongate, curved, subcylindrical, armed with two curved, divergent claws (Moznette, 1920). Legs with sharp, curved spur or thorn at the end of each fore leg (Tryon and Benson, 1920).

The beetle resembles grain weevil, but many times larger (Tryon and Benson, 1920; McCarthy, 1920).

Adults about 11 mm (Froggatt, 1923c) to 14 mm

(Fawcett, 1913) in length and 4 mm (Moznette, 1920) to 4.23 mm (Pinto, 1928) in breadth with rostrum measuring 1/8 inch (3.17 mm) (Pinto, 1928) to 4 mm (Fawcett, 1913) in length.

No marked difference between sexes is observed (Tryon and Benson, 1920; McCarthy, 1920; Pinto, 1928; Simmonds, 1933) except that males are usually slender than females (Pinto, 1928). Female has the proboscis slightly longer and narrower than that of the male (Tryon and Benson, 1920). First ventral abdominal segment of male was more or less strongly impressed in the middle, while in female it is flat or even slightly convex. Rostrum of male is more coarsely punctured and the punctures though becoming finer extend almost to the apex, where-as in female the apical half of the rostrum is practically smooth (McCarthy, 1920).

Bionomics of *C. sordidus* :

Egg : The female beetle laid eggs singly in the outer leaf sheaths of the banana. The eggs were more often deposited on the stools just above the bulb, and on sheaths that were partly decayed (Moznette, 1920; Gendana, 1922; Edwards, 1925; Braithwaite, 1963; Ruiz, 1973). The female after selecting a site just above the ground level where stem and bulb join, ate out a small tunnel and turning round

deposited the eggs in the bottom of the tunnel (Moznette, 1920; Cendana, 1922; Froggatt, 1925; Urich, 1925; Sen and Prasad, 1953). The incision was made horizontally or slightly downward into the outermost leaf sheath, by means of her beak or snout. She then reversed her position and laid a single egg at the bottom of this pouch (Cendana, 1922). Different workers have stated that the eggs were laid in different locations. A few eggs were laid loosely in the slightly decayed leaf sheath (Moznette, 1920). Eggs were deposited singly upon the base of the banana stem near the crown, less often on the bulb beneath the soil (Jepson, 1914). The eggs were laid on the surface of the bulb below the ground level (Watts, 1917) or laid mostly in corms and in fallen stem (Weddel, 1945) or laid in a small burrow among decaying leaf bases at the crown or in a crack in a similar situation (Roy and Sharma, 1952) or laid between leaf sheath scars on the crown just above the ground (Feakin, 1971), egg laying half an inch above the level of soil (Fawcett, 1913), or a few inches above the surface (Jepson, 1914) or laid about 25 cm from the surface of the ground (Cendana, 1922).

Incubation period varied greatly depending on temperature. Eggs hatched in 3 days (Swain, 1952) to 28 days (Weddel, 1945).

Grub :

The number of moults as reported by previous workers varied from two (Froggatt, 1923a) to six (Cendana, 1922).

Larval period was found to vary according to climatic conditions from 12 to 165 days (Fiji - Fawcett, 1913; Jepson, 1914; Florida - Moznette, 1920; Queensland - Tryon and Benson, 1920; Froggatt, 1921, 1922b, 1923a,c, 1924b,c, 1925; Weddel, 1948; Philippines - Cendana, 1922; Brazil - deAzevedo, 1922; Ceylon - Jardine, 1924; Pinto, 1928; Mauritius - Edwards, 1925; Trinidad - Urich, 1925; Uganda - Harris, 1947; Hill, 1975; Nicaragua - Swain, 1952; Formosa - Cheng, 1957; El Salvador - Siliezar, 1961; Trezo, 1969; Sao Tome - Schmidt, 1965).

Full grown grub tunnelled its way downwards and made a roomy cell near the epidermis of the bulb where it transformed into pupa (Jepson, 1914; Moznette, 1920; Cendana, 1922; Froggatt, 1925; Braithwaite, 1963). Pupal chamber was found lined with excreta (Fletcher, 1914).

Prepupa :

Fully grown grub stayed in a comatose condition for three days before changing into pupa (Pinto, 1928). It stayed dormant for a time exhibiting but little powers of

movement if disturbed. Prepupal stage lasted for 1 to 3 days after which the larval skin was lost exposing the pupa (Froggatt, 1922; 1925; Roy and Sharma, 1952).

Pupa :

Pupal chamber was situated below ground level and just underneath the bulb, and also observed as far as two inches from the bulb in cases of heavy infestation. No cocoon was formed but occasionally a few strands of fibre were noticed at the tunnel end of the chamber. This generally occurred in dry material or in tissues of leaf bases (Froggatt, 1925; Roy and Sharma, 1952).

Variation in pupal period was observed depending on climatic conditions. The period varied from five days to fifteen days (Fiji - Fawcett, 1913; Jepson, 1914; India - Fletcher, 1914; Queensland - Tryon and Benson, 1920; Froggatt, 1921, 1922b, 1923a, 1924b, 1925; Philippines - Cendana, 1922; Brazil - de Azevedo, 1922; Mauritius - Edwards, 1925; Trinidad - Urich, 1925; Ceylon - Pinto, 1928; Uganda - Harris, 1947; Hill, 1975; Formosa - Cheng, 1957; El Salvador - Siliezar, 1961; Sao Tome - Schmidt, 1965).

Adult :

Adult weevil after emerging from pupa remained dormant in the pupal chamber for 6 to 7 days (Froggatt,

1921; 1923), 3 to 6 days (Jardine, 1924), 4 to 5 days (Edwards, 1925), then the adult pushed its way out of the bulb (Cendana, 1922).

Life Cycle :

Total life cycle from egg to adult varied considerably, depending on the temperature from 29 to 180 days (Jamaica - Anonymous, 1917; West Indies - Watts, 1917; Philippines - Cendana, 1922; Queensland - Froggatt, 1922a,d, 1924b, 1925; Trinidad - Urich, 1925; Belgian Congo - Ghesquiere, 1927; Mauritius - Moutia, 1931; Uganda - Harris, 1947; New South Wales - Braithwaite, 1963). C. sordidus had four generations annually in Taihoku (Shiraki and Sonan, 1937), not more than five generations in Philippines (Cendana, 1922).

Adults were found to be gregarious in cavities and depressions in the outer leaf sheaths of banana close to the ground level and also below the surface (Moznette, 1920). It hid in a leaf sheath or below ground level near the corm on which it fed (Edwards, 1925). It lived in rotting stems where the humidity was very high. Infact, the adult weevils were always moist (Whalley, 1957), came out of ground and sought hiding place among decaying leaf sheaths (Cendana, 1922). Weevils were sluggish in movement and feigned death or 'Play possum' on being disturbed (Moznette,

1920; Froggatt, 1925).

Adults were sluggish and most active during the hours of darkness (Harris, 1947), particularly sluggish during colder portions of the year (Froggatt, 1922d). Their period of greatest activity was from 6 O'clock in the afternoon to 6.0'clock in the morning (Cendana, 1922). Adult moved only at night over the soil and air, during day time remained underneath soil or in crevices. In dull weather immediately after rains they came on to the soil (Roy and Sharma, 1952). Beetles were found to be adhorrent to light (Froggatt, 1924).

No damage was done by the adult, the function of adult being purely reproduction (Froggatt, 1925; Roy and Sharma, 1952). The food of adult weevil was undoubtedly the substance of the banana plant i.e., corm or the material of rotting stems (Froggatt, 1921, 1925). Its normal food was dead or dying banana plants (Hill, 1975).

The longevity of the adult was not known but they lived in dry earth without food for three months (Fawcett, 1913) or two months (Moznette, 1920) and not longer than 17 weeks with food (Fawcett, 1913), lived for two years (Harris, 1947; Schmidt, 1965; Simmonds, 1966), 5 to 8 months (Jardine, 1924). The longevity of imagoes ranged from 471 to 483 days (Froggatt, 1923), 16 to 21 months (Froggatt, 1924), 16 weeks

(Jepson, 1914), 103 days in captivity (Cendana, 1922). The average life of the beetle in the laboratory was as high as 748 days. Under starved conditions the life was short, when the soil was dry being only a few days. When the soil was kept damp it might extend to six months (Froggatt, 1925). Adults lived for considerable time without food (Cendana, 1922). In dry soil, they died without food within 5 to 6 days and if soil was damp they were found to live for more than 100 days in cooler months, lived for 70 to 121 days without food in damp soil (Froggatt, 1924). If exposed to dry sun they died in few seconds (Froggatt, 1923). In submerged conditions they survived for 120 hours (Froggatt, 1923), withstood 12 days of complete submergence (Froggatt, 1924).

Beetles were nocturnal (Moznette, 1920; Simmonds, 1966), they came out during night to feed and lay eggs (Simmonds, 1966).

There was a period of about one month from the emergence of the female beetle until the first eggs were laid (Froggatt, 1923). Preoviposition period ranged from 14 to 99 days (Froggatt, 1922b,d, 1925).

Egg laying throughout life, influenced only by seasonal climatic variations, decreasing with advent of cold weather and also possibly by the age of the insect. Ovi-

position more in early part of life of 16 to 21 months (Froggatt, 1922d, 1924c).

Total number of eggs laid by a female varied between 10 to 15 and in exceptional cases hundred (Simmonds, 1966). Each female laid 14 eggs or less (Tryon and Benson, 1920), 10 to 50 eggs or more (Hill, 1975).

During copulation, the male surmounting the female, hung down well over the pygidium of the latter, thus bringing its penis and vagina into close juxtaposition, in this position connexion took place. This act took place readily in captivity (Froggatt, 1923c).

Reproduction was throughout the year (Urich, 1925). During the heat of summer and cold of winter breeding was much less compared to spring and autumn (Froggatt, 1923b).

According to Simmonds (1933) out of 100 adults taken at random 54 were males and 46 females.

By using traps Freeman (1919) collected 644 adults during December, 511 in January, 270 in February, 341 in March from an area of  $\frac{3}{5}$ th of an acre. Where as Froggatt (1925) collected 30,000 beetles between February and July, in August 1222, September 1472 beetles. According to Gomez Clemente (1947) number of beetles collected reached peak in January,

February, March, October, November and December. Wallace (1938) reported that the beetles came freely to the baits in the months of September to April and there was complete avoidance of bait in the depth of winter.

Route and mode of infestation :

C. sordidus was undoubtedly distributed from one country to the other and from one plantation to the other by the transportation of infested suckers and root stocks used for propagation purposes (Cendana, 1922; Roy and Sharma, 1952; Schmidt, 1965) and spread was also by crawling from infested area to the newer plantation (Cendana, 1922; Roy and Sharma, 1952; Braithwaite, 1963), or by flying (Froggatt, 1925; Roy and Sharma, 1952). Sometimes it spread by washing down due to rain water or flood water in gullies and steep slopes (Froggatt, 1925; Roy and Sharma, 1952).

According to Wallace (1938b), the beetles were found to have migrated across a belt of Paspalum dilatatum whose width varied from 12 to 34 yards. However, considering the fact that a clean new plantation had been growing for 16 months so close to the heavily infested old plantation, the degree of infestation seemed very small.

Flight :

Experiments carried out both in field and laboratory to test the power of flight showed that the beetles never attempted to expand their wings (Froggatt, 1923a). However, according to Urich (1925) the adults were able to fly. Watts (1917) stated that they flew during night and they were not attracted to light.

Experiments in field and specially prepared trays indicated that although flight probably did occur at times, it was practically negligible as a factor in the spread of the pest. Both sexes, particularly, females, migrated frequently and rapidly, especially during warm heavy rains in November - January. Migrations occurred on warm humid night during certain seasons of the year and that contrary to the results of previous investigations flight was a major factor in them (Simmonds, 1929; 1932, 1935).

Froggatt (1924b), based on the data received from Queensland farmers who observed that in one case beetles were found in a vessel just inside, in another in a vessel outside the house, stated that under undefined conditions the adult weevils did fly. In another instance, the beetles flew into a room through a large open shutter a little after 7 p.m. on a warm, cloudy night early in February. In another

instance the beetle flew at night to a height of about 12 feet, on to a table in the verandah of a house situated close to banana stools. The climatic conditions were given as "muggy after a few days of solid rain". This occurred during the first week of March. The same author in 1925 stated that flight normally occurred on "warm muggy nights shortly after dusk", for the most part between the later part of November and first half of April.

Varietal resistance :

Banana borer C. sordidus was apparently confined to the banana, all varieties of which were attacked impartially (Gowdey, 1923; Roy and Sharma, 1952). All varieties like 'Gingeli' and 'Banana Carree' in Mauritius (d'emmerez and Gebert, 1921), Cavendish, Lady's finger, Sugar banana, Plantain, Gros Michel, Dacca in Queensland (Froggett, 1921; 1925), Musa fehi in Francais de l'océanie (Millard, 1952), M. accuminata sub. sp. siamia in Malaya and Banksii in Queensland (Hord and Flippin, 1956), M. paradisiaca, M. arnoldiana, M. textiles in Belgian Congo (Ghesquire, 1927), were found to be infested severely.

Variety Lacatan was also attacked to some extent in Philippines (Cendana, 1922), some varieties like Cango, Java and Nanica showed some resistance in Brazil (Elias, 1960).

Variety Gros Michel was more susceptible than Boutround (probably Lacatan) in Honduras (Herd and Flippin, 1956). Plantain (Musa sapientum var. paradisiaca) was more preferred than banana in Puerto Rico (Wolcott, 1934) and variety Makabou in St. Lucia appeared to be less susceptible (Hutson, 1918). In Honduras, Musa balbisiana seemed to be rather resistant (Herd and Flippin, 1956). In India, varieties like Alpan, Champa, Kothia, Malbhog, Barsani, Batisa-Malbhog were found to be more susceptible compared to Batisa which was the least susceptible (Sen and Prasad, 1953).

M. sapientum was less resistant, than M. nana.

M. brieii and M. emaculata were found to be resistant to the beetle attack, while M. sapientum was found comparatively less resistant in Belgian Congo (Ghesquiere, 1927).

According to Simmonds (1966), C. sordidus attacked only members of the genus Musa and no cultivar was known to possess any useful degree of resistance to the pest.

#### Chemical control of banana rhizome weevil :

Gravier (1907), suggested immersion of bulbs in Bordeaux mixture. Sodium arsenite dust and spray, mercuric chloride spray, barium chloride spray, lead arsenate dust, Paris green dust, Paris green flour mixture, calcium arsenate

dust and borax dust were tested against banana borer and found that dusts were more satisfactory than sprays. Paris green was the most satisfactory (Froggatt, 1922d, 1923b,c, 1925, 1928). Paris green flour mixture was further proved to be effective (Gowdey, 1923; Wallace, 1937; Roy and Sharma, 1952).

According to Froggatt (1923a,c) and Gowdey (1928), paradichlorobenzene was effective against weevil while Smith (1929) reported that paradichlorobenzene was not satisfactory.

DDT in comparison with other insecticides like, BHC, polychlorocyclohexane sulphide, DNC, dieldrin and aldrin was not effective (Cullie, 1950; Cheng, 1957). However, spraying of DDT 0.16 per cent minimised the attack of weevils (Sen and Prasad, 1953).

Chlordane 20 per cent and aldrin 25 per cent were found to be effective (Swain, 1952). It was observed that dieldrin and aldrin mixtures applied annually at the rate of 2 lbs per acre protected the crop (Simmonds and Simmonds, 1953). Batchelder (1954) tried toxaphene, chlordane, aldrin and dieldrin as drenching sprays. Dieldrin was superior in residual toxicity and performance.

According to Whalley (1957), 0.5 per cent dieldrin dust proved to be easy and safe to use under all conditions.

Aldrin (2 lb a.i. per acre) and dieldrin (1 lb a.i. per acre) were found to offer excellent control in comparison to lindane (8 gm. a.i. per acre) the performance of which was poor (Braithwaite, 1958). Leach's (1958) experiment showed that dieldrin spray at 1.5 lb toxicant per acre applied to the base was much superior to  $\gamma$ -BHC. Also dust applications of 50 per cent WP of dieldrin in gypsum (4:96) to soil around base of each plant mat after removal of trash or in artificial fertilizers around the roots at 2 lb dieldrin per acre reduced the number of weevils caught in traps.

According to Braithwaite (1963), 0.05 per cent a.i. of dieldrin or 0.1 per cent a.i. of aldrin or 0.1 per cent a.i. of heptachlor at one pint per plant was found to be effective (Wolfenbarger, 1965; Deang, 1969). Wolfenbarger (1965) observed that granular formulations were slightly effective than emulsions. Braithwaite (1967) tested aldrin at 1, dieldrin at 0.5 and heptachlor at 0.5 and 1 lb a.i. per acre and found that these insecticides controlled banana borers effectively. Three organophosphorous insecticides viz., diazinon, fenchlorphos and Bayer S4400 (1 lb a.i. per acre) were also tested and they were relatively ineffective against banana borer.

Adult weevils may be destroyed by attracting them

on to small chopped sections of old pseudostem which have been dusted with 2-isopropoxyphenyl-N-methyl carbamate (Anonymous, 1969a). Adults exhibited high resistance to aldrin and dieldrin and less resistance to  $\gamma$ -BHC (Edge, 1974).

Pullen (1973) tested pirimiphosethyl (Pirimicid, 5, 10 and 50 per cent) at 1.5 and 2.5 gm a.i. per plant, terracur p' (fensulfothion 7.5 per cent) at 3 gm a.i. per plant and Kepons<sup>2</sup> (Chlordecone, 5 per cent) at 3 gm a.i. per plant applied in a circle of weed free soil around the plant. Pirimiphosethyl formulation gave persistent control of G. sordidus comparing favourably with the other two treatments both in terms of action and persistence of control.

Resistance to dieldrin was suspected in banana borer by Shanahan and Goodyear (1974) when individuals in samples survived topical application of 1 micro litre of 0.25 per cent dieldrin.

Roberts (1956), reported that an aerial application of granular dieldrin gave some control. Bullöck and Evers (1962) tested 10 per cent granules of aldrin, dieldrin and heptachlor at the rate of 2 lb a.i. per acre (1.12 oz per mat) and noticed that dieldrin was superior to the other two insecticides. Terracur p' 10 per cent granular organophosphate

at the rate of 30 gm per plant on clean soil controlled banana borer effectively (Anonymous, 1969b).

Gaud, et al., (1975) tested kepone 5D, diazinon 14G, Dieldrin 15EC, dasanite 15Gr, disulfoton 10G (disyston 10Gr; lannate 90S); carbaryl (sevin 30WP; 80WP), parathion 15WP, carbofuran 10G (furadan 10Gr) and found that dieldrin 15EC at 5 ml, carbofuran 10G (furadan 10Gr) at 10 gm, dasanite 15Gr at 14 gm. and kepone 5D at 2 oz per plant were most effective.

## ***MATERIAL AND METHODS***

### III. MATERIAL AND METHODS

A detailed study of the banana rhizome weevil was undertaken during the period from September, 1970 through September 1974. Adult weevils collected from infested banana fields around Nanjangud, Mysore district, were maintained as stock culture on rhizomes which in turn were placed in cylindrical jars (Fig. 1) covered with damp muslin cloth.

#### Mass rearing :

For mass rearing, the weevils were enclosed in pneumatic troughs containing banana pseudostem (3 cm in height) for feeding and ovi-position (Fig.2). The pseudostems were changed once in four days. The eggs were collected along with a strip of pseudostem and were placed in pneumatic troughs (18 cm x 12 cm) containing moist sand at the bottom to a depth of 2 cm and closed with damp muslin cloth (Fig. 3). Subsequently grubs were transferred on to the rhizome (15 cm in height and 4 cm in diameter) for further development.

#### Survey and seasonal fluctuation of weevils :

Field observations on the incidence of the pest and seasonal fluctuations in the population of the weevil were

Fig. 1 : Cylindrical glass jar used to maintain  
the stock culture of Cosmopolites sordidus

Fig. 2 : Pneumatic trough used for feeding and  
oviposition of C. sordidus



Fig.1

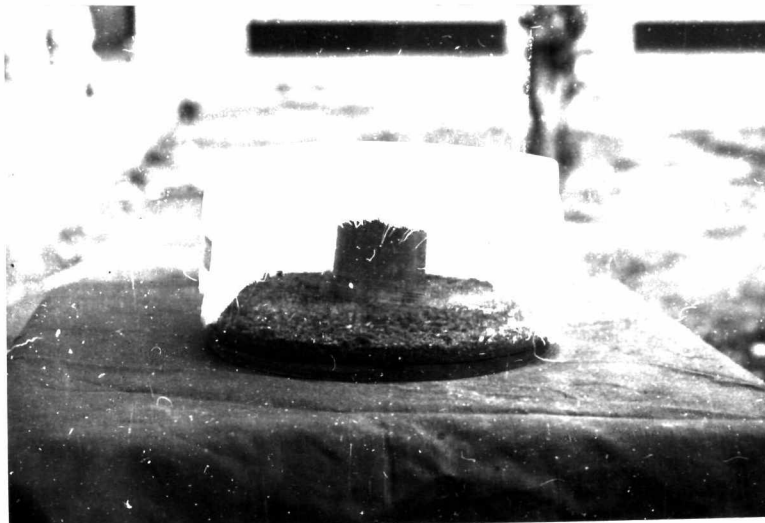


Fig.2.

carried out in the two infested fields (3 acres and 1.5 acres) around Nanjangud at intervals of two to three weeks. Traps of split pseudostems measuring 30 cm in length were placed with the cut surface against the soil close to the base of plants and were covered with trash in order to assess the population. Ten such traps were placed per acre at random. Counts of weevils noticed at each trap (after 24 hours) were considered as indicative of the fluctuations of weevil population in the garden. Studies using traps were carried out for two years from September, 1971 to September, 1973.

A survey was conducted during the year 1973, in major banana growing areas of the State, viz., Bangalore, Belgaum, Bellary, Chikkamagalur, Chitradurga, Coorg, Dharwar, Hassan, Kolar, Mandya, Mysore, North Canara, Shimoga, South Canara and Tumkur, to know the distribution of the pest. In each area three plots of one acre each were selected randomly and in each plot ten traps were placed at random. The incidence in these areas were recorded according to the following scale by counting the number of weevils: < 5 - low infestation; 5-10-medium infestation; > 10 - Heavy infestation.

Life cycle :

Studies on the life cycle of the weevil were carried out in the laboratory. Freshly emerged individual pairs of weevils were released in pneumatic troughs with moist sand at the bottom on which a piece of pseudostem (8 cm in length) was placed (Fig. 2) and the top covered with damp muslin cloth. A pair of weevils were released to each pneumatic trough and ten such troughs were maintained. Earlier observations, in which the food was changed every day revealed no egg laying or egg laying in negligible numbers and appreciable number of eggs being laid on the second day, when food was not changed and weevils least disturbed. So the pseudostems were replaced every alternate day. Such of those strips of pseudostems which had eggs were then placed in separate pneumatic troughs (18 cm x 12 cm) to study the incubation period of the eggs. On hatching, the grubs were transferred to fresh pseudostems of 8 cm height (Fig. 4). The pseudostem was preferred to rhizome for laboratory studies as tunnel caused by grubs was easy to locate. Since there was no blackening of the tissue, head capsule could be easily located and pseudostems were easily available. Before introducing the grubs, a small hole was made with the help of sterilized blunt iron rod on the leaf sheath into which a grub was introduced. Fresh food was provided every

Fig. 3 : Pneumatic trough containing banana  
pseudostem strips with eggs of C. sordidus

Fig. 4 : Fresh pseudostem used for studying the  
life cycle of C. sordidus

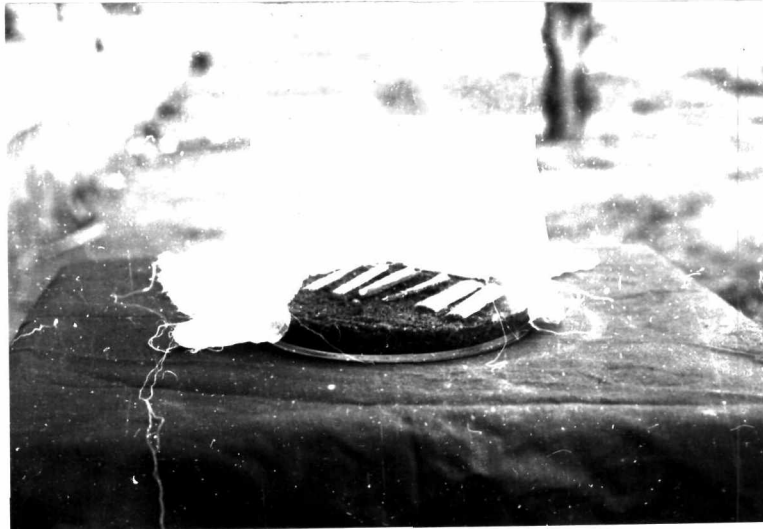


Fig.3



Fig.4

alternate day. For recording the number and duration of instars, the grubs were taken out of pseudostem and the tunnels were examined for moulted head capsule. This procedure involved frequent disturbance to developing grubs. Two undisturbed series were run simultaneously every time to study the entire life cycle, one on pseudostem and the other on rhizome. The same procedure was adopted in the determination of the time of pupation, duration of pupal period and emergence of adult weevils.

The same set explained above was used for determining pre-oviposition, oviposition and post-oviposition periods, fecundity and longevity of the adult.

Another experiment was conducted to determine the survival period of the adult weevils with and without food, and in dry and wet soil. Long plastic cups were used (Fig. 5). Two sets having moist soil with and without food and another two sets having dry soil with food and without food were maintained under observation. Twenty five weevils were enclosed for each set.

#### Flight habits :

Three experiments were carried out to induce flight in the adults of Cosmopolites sordidus to know their ability of dispersal by flight in search of food.

**Fig. 5** : Plastic cups used for the study of adult longevity of C. sordidus under different conditions



Fig.5

In the first experiment, four cylindrical jars (20 cm in height, 15 cm in diameter) with 5 cm of wet sand were taken and ten weevils were released into each jar. Food was not supplied to the weevils during the entire observation period of one week.

In the second experiment, a glass trough with a diameter of 20 cm was taken. In the centre of the trough a piece of banana pseudostem (15 cm height, 7 cm diameter) was placed and water was added to a height of 5 cm. Ten weevils were allowed on the pseudostem and left for one week for observation.

In the third experiment ten weevils were taken to which thread was fixed on their pronota with the help of wax and were hung in the incubator. The temperature of the incubator was raised to 35°C and the humidity was maintained at 65 to 70 per cent with the help of two plastic troughs filled with water. Both troughs were connected by a thick band of cotton.

#### External morphology :

Morphology of larvae and adults were studied by preparing slide-mounts of various parts by adopting the following method. The larva was killed by dipping in hot water for one or two minutes. It was then dissected to

remove the internal content and kept in 10 per cent KOH solution for varying periods of a few hours to a week depending upon the parts. The digested material was washed several times in water and dehydrated in a mixture of glacial acetic acid and carboic acid (1:1), carboxylol (1:1) and xylol alone, keeping for 5 to 15 minutes in each of the above. The dehydrated material was mounted on micro slides using canada balsam as a mountant. These slide-mounts were dried and used for description and for making diagrams.

The details of the characters that could be seen under a phase contrast microscope are shown in the diagrams. A stereobinocular was used for the description and drawing of different stages like grub, pupa and adult.

Host range :

To study the suitability of different plants as hosts in the laboratory, host materials obtained from local market were placed inside pneumatic troughs and each one was replicated thrice. Five pairs of weevils were released in each trough and the mouth closed with damp muslin cloth. Observations were made once in 15 days, for the survival of the adults and the development of the infestation if any. Similar experiment was conducted to study the development of grubs by releasing five grubs in each of the host material.

The following hosts were used.

<u>Common name</u>	<u>Scientific name</u>	<u>Family</u>
1. Elephant foot	<u>Amorphophallus</u> <u>campanulatus</u> Blume	Araceae
2. Sweet potato	<u>Ipomoea batatas</u> (linn.) Lam.	Convolvulaceae
3. Canna	<u>Canna orientalis</u> Rose.	Cannaceae
4. Tapioca	<u>Manihot esculenta</u> Crantz	Euphorbiaceae
5. Potato	<u>Solanum tuberosum</u> L.	Solanaceae

Varietal resistance of banana to rhizome weevil :

Fifteen varieties of banana (Table II) were collected from Pineapple and Banana Research Station, Trichur in Kerala. These varieties were selected after discussions with the scientists of the Department of Horticulture, Agricultural College, Hebbal, Bangalore. These varieties represented majority of the genomic groups under the family Musaceae. These varieties were screened for their resistance to the weevil attack. The experiment based on randomised block design consisted of fifteen treatments replicated three times. Each replication was grown in 50 x 50 x 50 cm cement cistern. They were filled with red sandy loam soil initially to a depth of 20 cm; suckers were

Table II

Different varieties of banana used for varietal resistance studies and their genomic constituency

S.No.	Variety	Genomic constituency	Code
1	Lacatan	AAA	A
2	Cavendish (Robusta)	AAA	B
3	Cavendish (Dwarf)	AAA	C
4	Virupakshi	AAB	D
5	Sirumeli	AAB	E
6	Nendran	AAB	F
7	Rasabale	AAB	G
8	Budubale	ABB	H
9	Nallabonthe	ABB	I
10	Peykunnan	ABB	J
11	<u>Musa balbisiana</u> Colla	AA	K
12	<u>Musa acuminata</u> Colla	AB	L
13	Neypoovan	AB	M
14	Poovan	AAB	N
15	Maduranga	ABB	O

placed and remaining space was filled with a mixture of sand, farm yard manure and red sandy loam (1:1:1) leaving a space of 15 cm from top rim. Twenty five adult weevils were released after thirty days of planting, and cultivation practices like fertilizers application, watering, removal of weeds etc., were followed uniformly for all the treatments. At the end of three months all the plants were uprooted and number of immature stages namely grubs, prepupae and pupae noticed was recorded. Based on the multiplication rate of the weevil and the extent of damage caused, the degree of susceptibility of each variety to the weevil attack was established.

#### Control of the banana rhizome weevil :

An experiment was carried out to evaluate four granular soil insecticides for their efficacy in the control of banana rhizome weevil. All the insecticides were tested at a single level applied once (Table III).

A completely randomised design with five treatments and six replications was used for this experiment. Banana suckers (variety: Budubale, group : ABB) were planted ones in cement cistern. Twenty five adult weevils were released on each plant at the time of planting. All other agronomic practices were followed uniformly for all cisterns throughout

Table III

Insecticides with their chemical names and the dosage used  
for the control of banana rhizome weevil

Treatment No.	Treatments	Dosage a.i./plant (in gm)	Amount of insecticide applied/plant (in gm)
T <sub>0</sub>	Control	-	-
T <sub>1</sub>	Phorate (Thimet 10G) O,O-diethyl S-(ethylthio) methyl phosphorodithioate	1.0	10.0
T <sub>2</sub>	Carbofuran (Furadon 3G) 2,3-dihydro-2,2-dimethyl- benzofuran-7-yl methyl- carbamate	1.0	33.0
T <sub>3</sub>	Disulfoton (Disyston 5G) O,O-diethyl S-2(ethylthio)- ethyl phosphorodithioate	1.0	20.0
T <sub>4</sub>	Quinalphos (Ekalux 5G) O,O-diethyl-O-[Quinoxaliny]- (2)-thionophosphate	1.0	20.0

the experimental period. Filling of cisterns was done as explained earlier.

Weighed quantities of the granular insecticides were applied one month after planting around the base of the plant and mixed with soil followed by watering. One month after the application of the insecticides, the plants were uprooted and the number of surviving grubs, pupae and adults was recorded in addition to the visual symptoms like marginal drying of leaves, dead heart etc.

## *EXPERIMENTAL RESULTS*

#### IV. EXPERIMENTAL RESULTS

##### A. EXTERNAL MORPHOLOGY OF THE LIFE STAGES

The external structure of different life stages namely egg, grub, pre-pupa<sup>Pupa</sup>, and adult is described in the following pages.

###### a. Egg :

The freshly laid egg is pure white, elongate, oval in shape (Fig.6). The length ranges from 1.80 to 1.98 mm (average, 1.92 mm) while the breadth ranges from 0.54 to 0.69 mm (average, 0.62 mm) (Table IV).

As the development of the egg progressed, the apical end of the egg gradually turns hyaline. A day before hatching the apical end of the egg turns cloudy and the mandibles of the developing grub appear as fine brown lines through the chorion. The gradual development of the mouth parts and the cranial sclerites of the grub are seen distinctly (Fig. 7).

###### b. Grub :

First instar : Head hypognathous, yellow with two pairs of black pigmented spots resembling ocelli, located above the base of the mandibles, anterior being larger than

Table IV

Measurements of egg, prepupa, pupa and adult (in mm) of  
C. sordidus  
(Average of twenty five)

	MINIMUM		MAXIMUM		AVERAGE	
	L	B	L	B	L	B
Egg	1.80	0.54	1.98	0.69	1.92	0.62
Prepupa	10.50	3.50	12.50	4.00	11.50	3.85
Pupa	11.00	3.50	12.50	4.00	11.45	3.90
Adult	11.00	3.50	14.50	4.00	12.55	3.75

Fig. 6 : Egg of Cosmopolites sordidus

Fig. 7 : Egg of C. sordidus showing the outlines  
of the head and mandibles

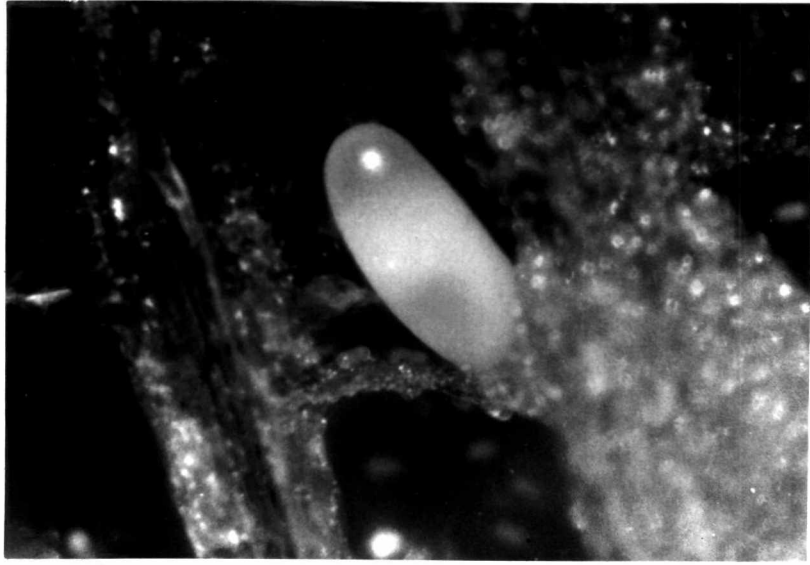


Fig.6

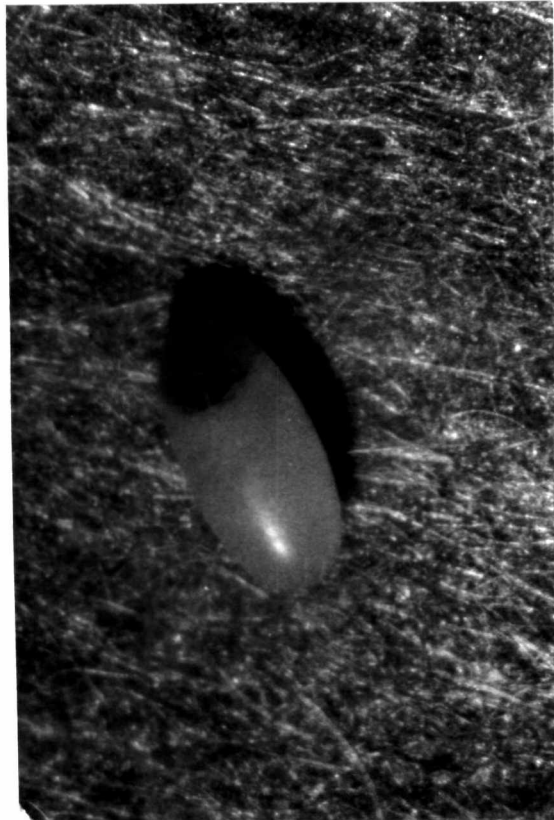


Fig.7

the posterior, irregular in outline and located at the base of the mandible. Epicranial suture inverted Y-shaped. Antenna single segmented, somewhat globular. Labrum flap like with U-shaped brown sclerotisation beneath. Mandibles longer than broad with two apical teeth, one longer and more prominent than the other. There is also a smaller, bluntly rounded lobe a little posterior to the second smaller one. Maxillae with two maxillary palpi and labium with two labial palpi distinct. Anterior margin of the head (Hypostomal and hypopharyngeal bracon) yellowish brown.

Thoracic and abdominal segments white, sparsely covered with setae of which those on 8th, 9th and 10th are prominent. The last three abdominal segments dorsoventrally flattened giving a truncate appearance to the abdominal tip. Two pairs of elongate, biforus spiracles placed dorso-laterally on the prothoracic and 8th abdominal segments are very prominent.

The length and breadth of the cranium are almost same and ranges from 0.45 to 0.51 mm (average, 0.48 mm). The body length ranges from 1.80 to 2.13 mm (average, 1.99 mm) while the breadth ranges from 0.60 to 0.81 mm (average 0.73 mm) (Table V).

Table V

Head and Body measurements of the different instars of Grub of C. sordidus  
(average of 25 larvae)

Instar	LARVAL MEASUREMENTS (In mm)											
	HEAD						BODY					
	MINIMUM		MAXIMUM		AVERAGE		MINIMUM		MAXIMUM		AVERAGE	
L	B	L	B	L	B	L	B	L	B	L	B	
I	0.43	0.43	0.51	0.51	0.48	0.48	1.80	0.60	2.13	0.81	1.99	0.73
II	0.57	0.57	0.66	0.66	0.61	0.61	2.40	0.99	2.85	1.14	2.64	1.03
III	0.72	0.72	0.81	0.81	0.76	0.76	3.45	1.29	3.90	1.53	3.72	1.39
IV	1.14	1.14	1.24	1.24	1.19	1.20	6.00	2.25	7.35	2.85	6.78	2.54
V	1.35	1.35	1.44	1.45	1.39	1.39	7.80	3.15	8.85	3.85	8.22	3.54
VI	1.74	1.75	1.83	1.84	1.79	1.80	9.30	4.20	10.35	4.80	9.90	4.46
VII	2.19	2.20	2.28	2.29	2.23	2.24	11.40	5.40	12.45	6.15	11.82	5.84

Second instar : Head brownish with deep brown coronal suture. Coronal suture more prominent with an internal keel, which extends anteriorly beyond the forking of the frontal sutures. Frontal sutures very pale. Frontoclypeal suture, hypostomal margin, hypopharyngeal bracon reddish brown. Ocelli two pairs, the anterior being more prominent, brownish yellow in color. Antennae translucent, of the same shape as in I instar. Mandibles reddish brown with darker margins, with the third apical tooth more prominent. Body fusiform. Other characters similar to I instar grub.

The length and breadth of head are almost same and ranges from 0.57 to 0.66 mm (average, 0.61 mm). The body length ranges from 0.99 to 1.44 mm (average, 1.03 mm) (Table V).

Third instar : Head yellowish brown with anterior margin of cranium reddish brown. Ocelli two pairs, darkly pigmented, anterior larger. Coronal suture extending beyond the forking of the frontal sutures. Body white. Other characters similar to first and second instars. Antenna single segmented, some-what bullet-shaped. Abdomen gradually broadening posteriorly.

The length and breadth of the head almost same and

ranges from 0.72 to 0.81 mm (average, 0.76 mm). The body length ranges from 3.45 to 3.90 mm (average, 3.72 mm), whereas the breadth ranges from 1.29 to 1.53 mm (average, 1.39 mm) (Table V).

Fourth instar : Similar to third instar grub in all respects except for the increase in size. Measurement of head (both length and breadth) ranges from 1.14 to 1.24 mm (average, 1.19 mm for length and 1.20 mm for breadth). The body length ranges from 6.00 to 7.35 mm (average, 6.78 mm) while the breadth ranges from 2.25 to 2.85 mm (average, 2.54 mm) (Table V).

Fifth instar : Similar to third and fourth instar grubs in all respects except for the increase in size. Head measurement almost same for length and breadth ranging from 1.35 to 1.45 mm (average, 1.39 mm for both). The body length and breadth range from 7.80 to 8.55 mm and 3.15 to 3.85 mm respectively (average, 8.22 mm for length and 3.54 mm for breadth) (Table V).

Sixth instar : Head reddish-brown in color with coronal suture and its anterior extension darker. Hypostomal and hypopharyngeal bracon dark brown. Mandibles dark brown with black margins having three incisor teeth. Body white, anterior and posterior spiracles with light brown margin.

All setae light brown in color. Other characters similar to fifth instar.

The head length ranges from 1.74 to 1.83 mm (average, 1.79 mm) and the breadth ranges from 1.75 to 1.84 mm (average, 1.80 mm). The body length ranges from 9.30 to 10.35 mm (average, 9.90 mm) and breadth ranges from 4.20 to 4.80 mm (average, 4.46 mm) (Table V).

Seventh instar (Final instar):

Head (Fig. 8) : Free, reddish-brown, rounded posteriorly. Clypeus (Fig. 9) paler with 2 pairs of setae, the median pair being longer than the lateral pair, a pore in front of each lateral seta. Antenna consisting of one membranous article which bears a conical accessory sensory appendage and several minute setae (Fig. 10). Hypostomal and hypopharyngeal bracon dark brown; Frontal sutures distinguishable throughout their length. Coronal suture distinct, approximately one-half as long as head. A suture which forms straight extension of coronal suture (termed as endocarina by Anderson, 1947) is distinct, measuring on an average 0.58 mm.

Frons triangular with five pairs of setae; setae  $fs_1$ ,  $fs_2$  and  $fs_4$  short, subequal,  $fs_3$  and  $fs_5$  long, subequal.

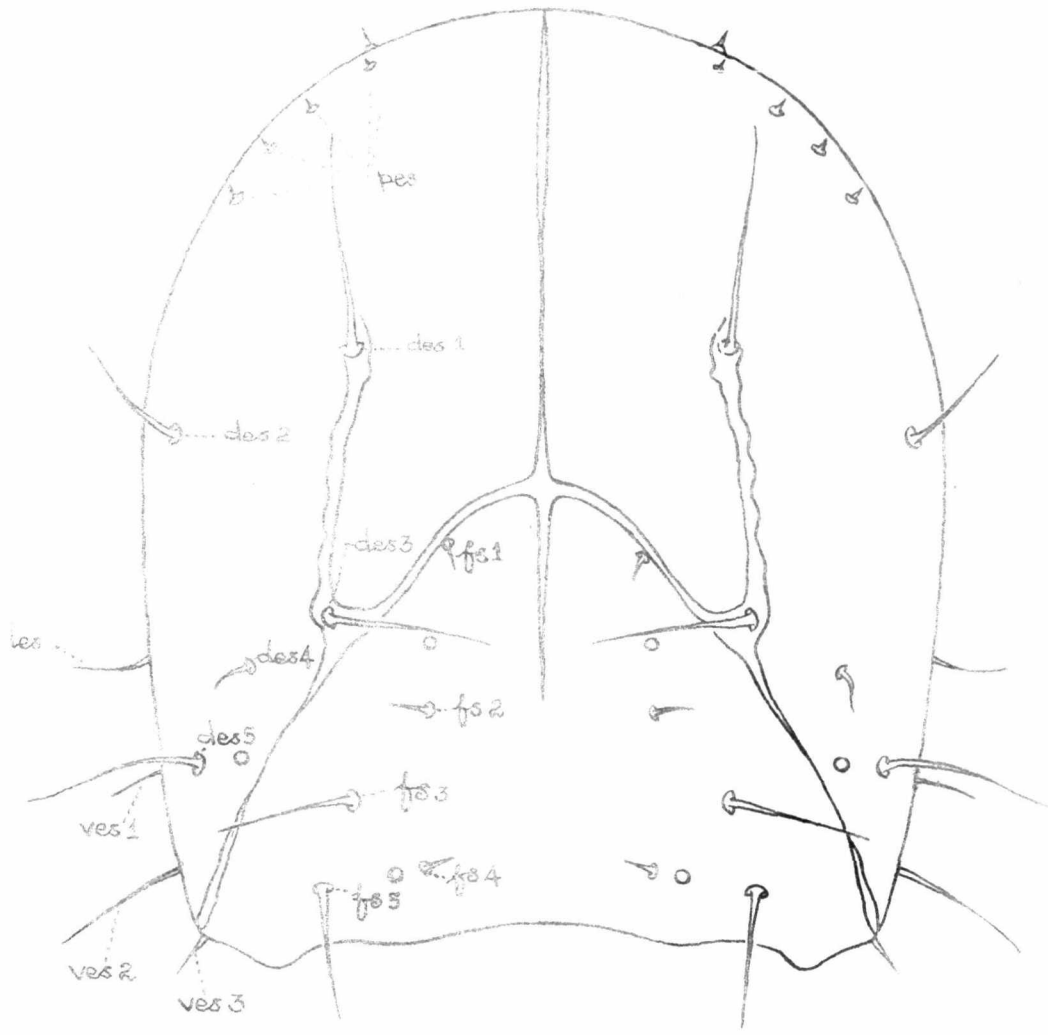
**Fig. 8 : Head of final instar grub of C. sordidus  
showing the setal pattern**

**des 1,2,3,4,5 = Dorsal epicranial setae**

**fs 1,2,3,4,5 = Frontal setae**

**pes = Posterior epicranial setae**

**ves 1,2,3 = Ventral epicranial setae**



1 mm

Fig. 8.

Two pairs of pores, one pair caudad of  $fs_2$  and the other just laterad of  $fs_4$ . Fourteen pairs of epicranial setae present. Five pairs of minute posterior epicranial setae (pes). Dorsal epicranial setae  $des_1$ ,  $des_3$  and  $des_5$  long and subequal,  $des_2$  moderately long,  $des_4$  short. Lateral epicranial setae (les) one pair, medium. Ventral epicranial setae (ves) three pairs,  $ves_1$  medium in length,  $ves_2$  long,  $ves_3$  short. A pair of pores mesad to  $des_5$  present.

The mouthparts are well developed and are of Chewing type. The labrum (Fig. 9) dark brown, semicircular and depressed below the level of clypeus; broader than long, upper surface with two pairs of setae, one pair situated close to the outer margins and the inner pair located above the U-shaped strongly sclerotised bridge of the epipharynx which is clearly seen from the dorsal side. Epipharynx (Fig. 11) has well sclerotised U-shaped bridge, the base of which extends beneath the clypeus. There are six pairs of stout, submarginal setae located along the anterior margin. These setae are blunt and branched, some bifid and other trifid and sometimes even more. In addition are twelve groups each consisting of a large number of fairly stout, unbranched setae, each group being located at the bases of anterior setae. U-shaped bridge with three pairs of broad, lanceolate setae along the inner margin of epipharyngeal rods; innumerable number of

Fig. 9 : Clypeus and labrum of final instar grub of C. sordidus

Cl = Clypeus  
cls 1,2 = Clypeal setae  
cls1 = Clypeal sensillum  
Lm = Labrum  
lms 1,2 = Labral setae

Fig. 10 : Antennae of final instar grub of C. sordidus

acap = Accessory appendage of the antennae  
art = Article

soft hair-like papillae on both sides of epipharyngeal rods and many stout papillae inside.

Mandible (Fig. 12) : Stout, more or less triangular with bluntly pointed three apical denticles, the anterior larger than the second and the posterior shortest and bluntly rounded; with two setae on the lateral outer side and two punctures. Molar area not very prominent.

Labio-Maxillary complex (Fig. 13) : This forms the ventral flap of the pre-oral cavity, and consists of a pair of maxillae and a largely membranous labium. Each maxilla is elongate, smooth and can be easily differentiated into the basal, small, transverse cardo and the elongate fused stipes and mala, which is longer than broad. No setae on cardo. Three prominent long setae, one more towards base of stipes, the other two close to the base of palp. Covering the mala a dense coating of setae; distally the mala with a series of broad setae some of which exhibiting a tendency to branch. In addition, a single short seta which is basally associated with a puncture is present at the base of the mala. Maxillary palp two-segmented, the basal segment being wider and longer than the distal one which is more or less conical in shape, two punctures present at the distal end of the basal palpal segment. A group of sensory pegs arranged at the distal tip of the second palpal segment.

**Fig. 11** : Epipharynx of final instar grub of C. sordidus

**als** = Antero - lateral setae

**ams** = Antero - median setae

**EpR** = Epipharyngeal rods

**msep** = Median setae of epipharynx

**Fig. 12** : Mandible of final instar grub of C. sordidus

**nds 1,2** = Mandibular setae

**ndsl 1,2** = Mandibular sensille

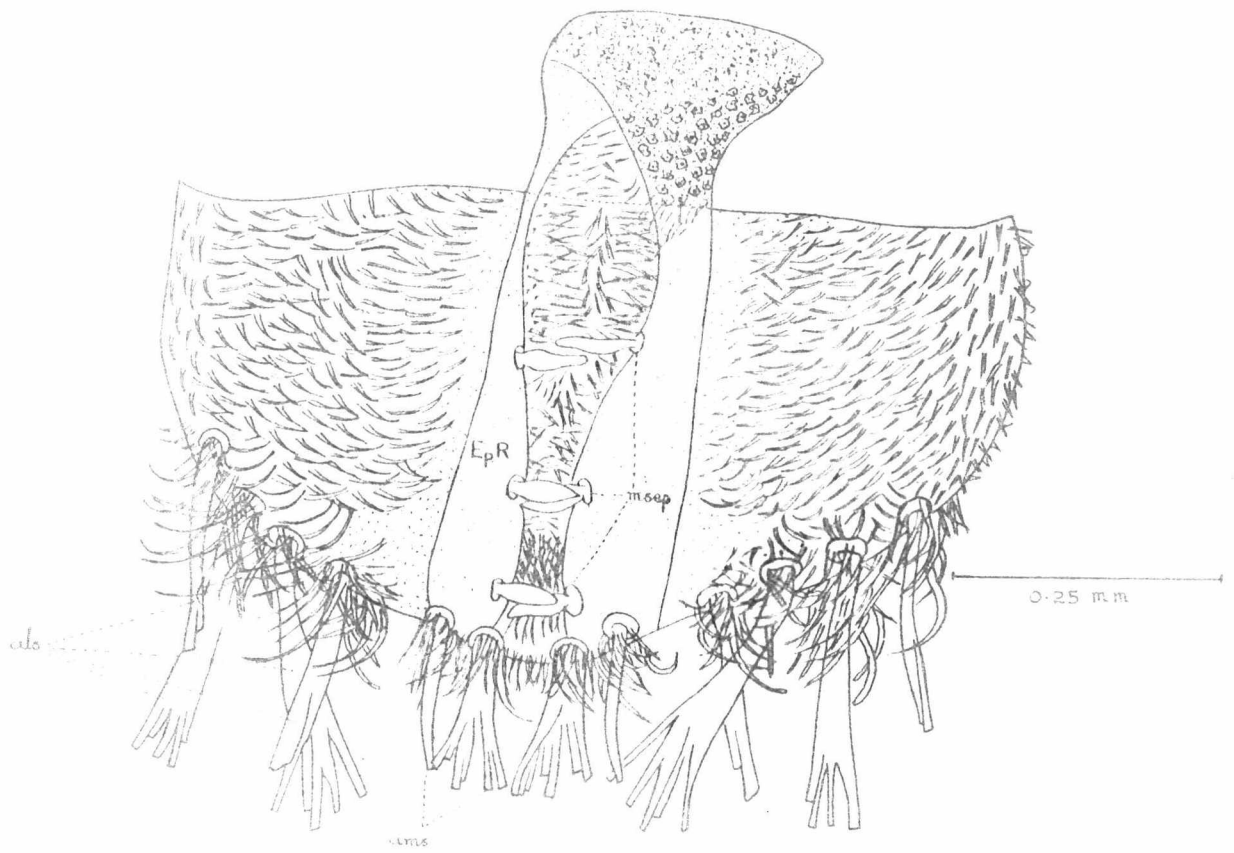


Fig. 11.

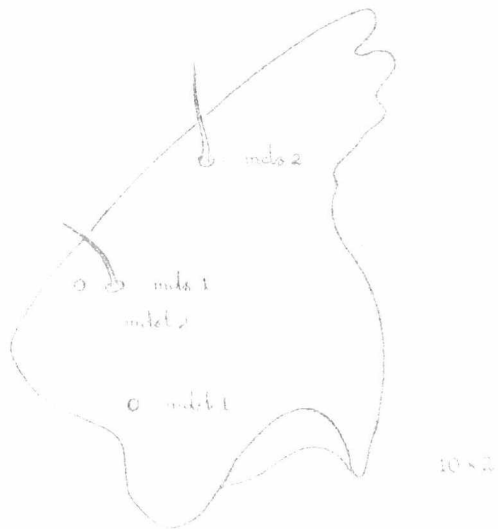


Fig. 12.

Labium located inbetween the two maxillae and largely membranous excepting a conical region between the palps which is sclerotised (Prementum). Three pairs of setae in the membranous area (postmentum). Three pairs of setae on the prementum, one mesad of the bases of palpal segments and other <sup>two</sup> anterior to it. Two pairs of punctures, one at the basal palpal segment and the other pair mesad of middle pair of setae. The broad ligular lobe was beset with a very large number of setae; Another pair of stout setae just anteriorly on ligula and these appear to be clubbed or chelate. Labial palp two-segmented, borne on a sclerotised palpiger, the basal segment broader and distal segment narrower and conical, having sensory pegs at the tip.

Body creamy white, glabrous, stout, fleshy, slightly curved anteriorly, apodous. Minute setae sparsely distributed all over the body. Dorsally, segments very much wrinkled and indistinct, ventrally segmentation more clear. The anterior spiracles (Fig. 14) located inbetween pro- and mesothorax on the sides and appear to lie close to the head. The spiracle elongate with a longitudinal slit. The first seven abdominal segments normal, the last two form a broad truncated posterior end. Each of the first seven bears a pair of minute spiracles. The segments increase gradually upto fifth segment and there after decrease in width. The seventh

Fig. 13 : Labio-maxillary complex of final instar grub of C. sordidus

bslm	=	Basal sensillum of mala
bsm	=	Basal seta of mala
C	=	Cardo
LbP	=	Labial palp
lis	=	Ligular seta
Ma	=	Mala
MxP	=	Maxillary palp
pms 1,2,3	=	Setae on postmentum
PMT	=	Postmentum
PrmS	=	Premental sclerite
prms	=	Setae on prementum
S	=	Stipes
sls	=	Sensillum of stipes
sma	=	Setae of mala
ss1,2,3	=	Stipeal setae

Fig. 14 : Spiracle of final instar grub of C. sordidus



Fig. 13.



Fig. 14.

segment is the smallest of the normal segments. The sloping of the truncate abdominal tip starts from 8th abdominal segment. The posterior spiracle located on eighth abdominal segment is similar to that of the anterior spiracle. The dorsum of the 9th segment flattened. The 10th segment is not clearly seen.

Chaetotaxy (Fig. 15,16) : The setal pattern as seen on one side of the body is presented here. Pronotum with 9 setae. Pleural area with two setae (pls), pls<sub>1</sub> medium and pls<sub>2</sub> long. Pedal area with a group of six setae, one long, one medium and the rest short and subequal. Sternal setae short. Meso- and meta-thorax with one prodorsal seta (prs) on prodorsum (Pr D) and three post dorsal setae (pds) on post dorsum. Pds<sub>1</sub> and pds<sub>3</sub> short, pds<sub>2</sub> medium. Alar area with one median seta. Spiracular area of mesothorax with one long seta. Pleural area with one medium seta, pedal area with six setae, two long, subequal, rest short, subequal. Sternal area with one seta shorter than the seta on sternal area of metathorax. Metathorax with 4 short setae on spiracular area, one epipleural seta, one pleural seta and six setae on pedal area, three long, subequal, three short and subequal.

Prodorsum of typical abdominal segment with one seta, medium in size. rostdorsum of typical abdominal segment

Fig. 15 : Semidiagrammatic sketch showing chaetotaxy of final instar grub of C. sordidus

Th I	=	Prothorax
Dpt	=	Dorsum of pronotum
PdA	=	Pedal area
Pl	=	Pleurum
pls1	=	Pleural setae
pls2		
Sp	=	Spiracle
St	=	Sternum
Th II	=	Mesothorax
AlA	=	Alar area
pds1,2,3	=	Post dorsal setae
PrD	=	Prodorsum; prs = Prodorsal seta
PsD	=	Postdorsum
ss	=	Spiracular seta
Th III	=	Metathorax
Ab I,VIII,IX	=	Abdominal segments
eps	=	Epipleural seta
eus 1,2	=	Eusternal setae
Fld I,II,III	=	Folds on abdominal segments
IFld	=	Inter segmental fold of the abdominal segments
SpA	=	Spiracular area
sts	=	Sternal seta

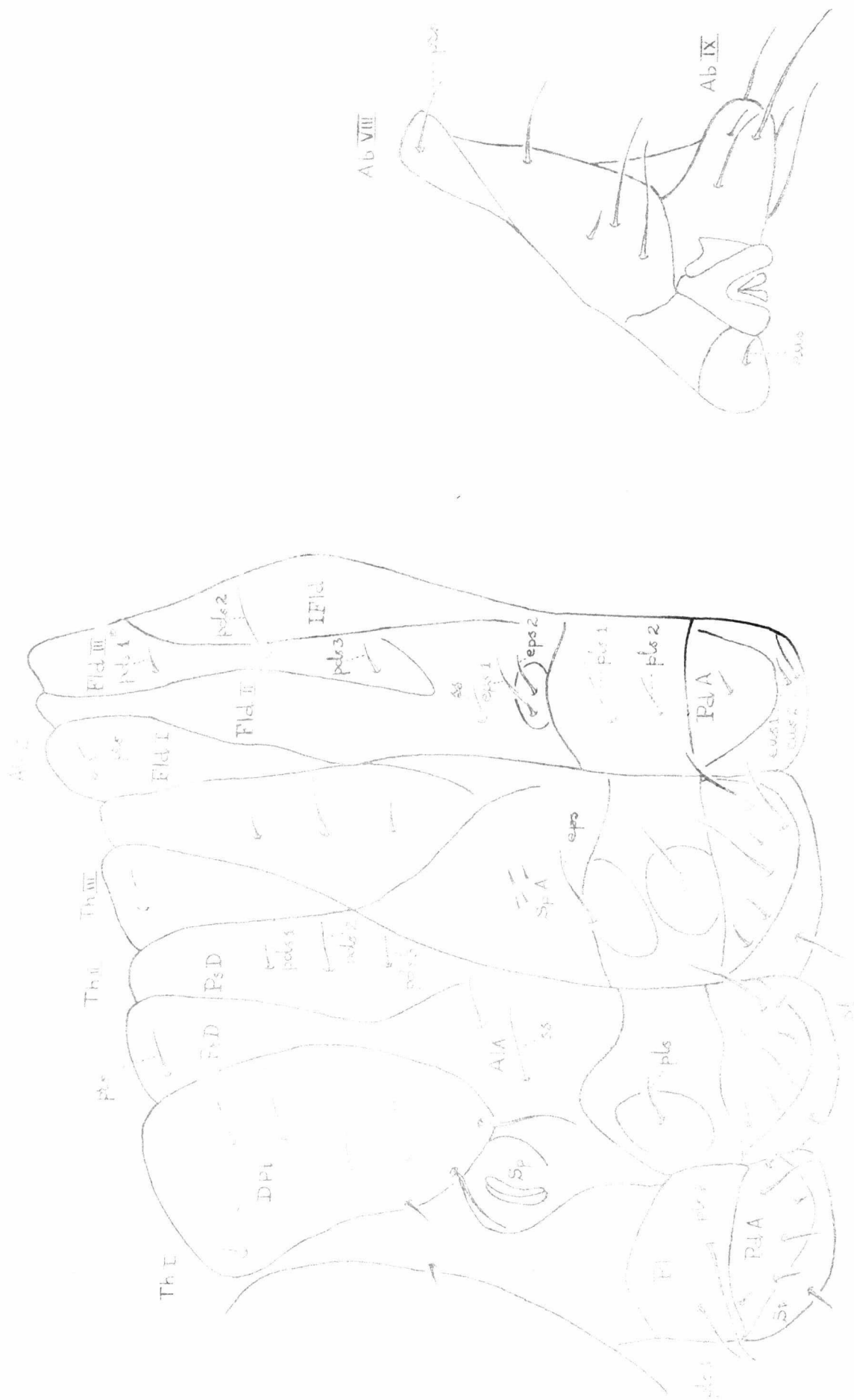


Fig. 15.

with three setae, seta 1 and 3 short, subequal and seta<sub>2</sub> long. Spiracular area with one seta, medium. Epipleural area with two setae one long, one medium. Pleural area with two setae one long, one medium. Pedal area with one short seta. Eusternum with two setae, one short, the other medium. Typical abdominal segments with three folds and one inter-segmental fold.

Eighth abdominal segment with one prodorsal seta, long. The slope with four setae, one placed towards mid dorsal line, the other three towards the lateral side, two long, one short. One eusternal seta. Ninth abdominal segment with six setae, four long, subequal, two short.

The head length ranges from 2.19 to 2.88 mm (average, 2.23 mm), while breadth ranges from 2.20 to 2.29 mm (average, 2.24 mm). The body length ranges from 11.40 to 12.45 mm (average, 11.82 mm) where-as breadth ranges from 5.40 to 6.15 mm (average, 5.84 mm) (Table V).

c. Prepupa (Fig. 17) :

Flaccid and elongate. Thoracic segments become prominent with distinct ventro-lateral lobes. The last moult takes place at the end of this stage. Prepupa on an average measures about 11.50 mm in length and 3.85 mm in width with a minimum of 10.50 mm and a maximum of 12.50 mm for length

**Fig. 16** : **Semidiagrammatic sketch of dorsal view of 8th and 9th abdominal segments of the final instar grub of C. sordidus showing the location of setae**

**Fig. 17** : **Prepupa of C. sordidus**

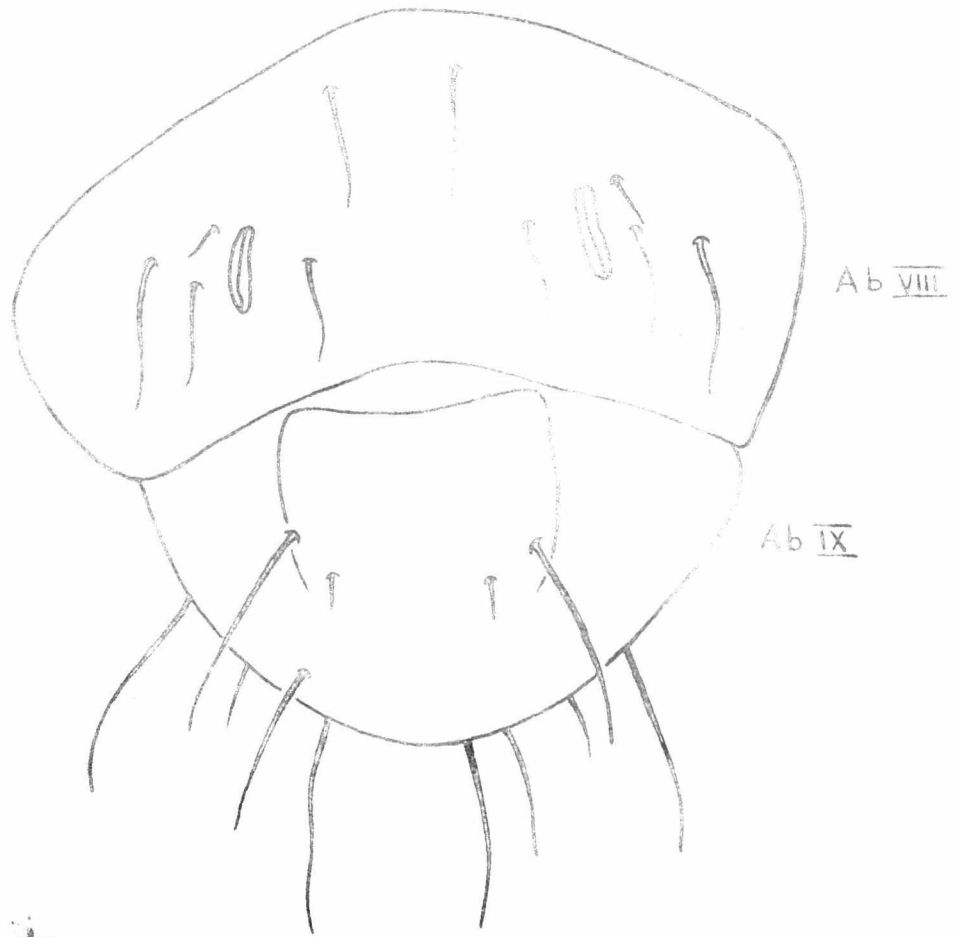


Fig. 5.

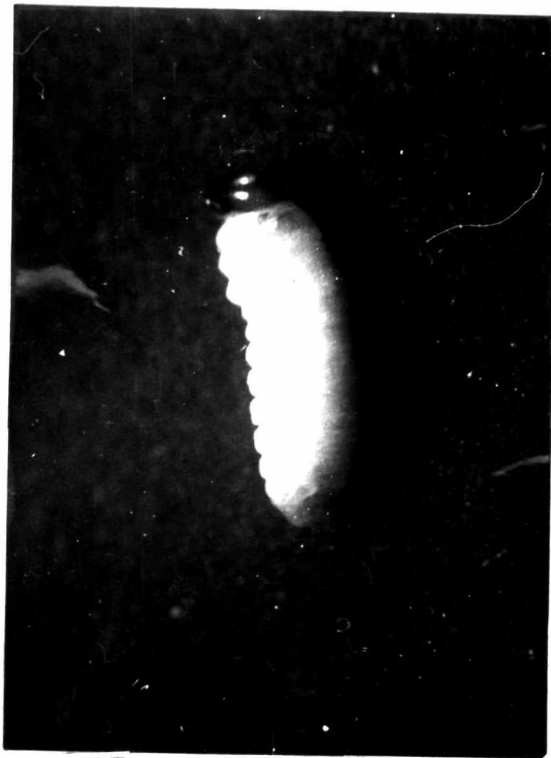


Fig. 17

and 3.50 to 4.00 mm for breadth (Table IV).

d) Pupa (Fig. 18) :

Exarate, elongate, white. The snout margin uneven with numerous depressions. On head a pair of long, brown setae, one on either side of mid-dorsal line; a pair of very small setae placed anteriorly and laterad of the above setae. On the snout are five pairs of setae distributed dorsally, of which one longer and stouter pair; the second pair anterior and mesad of the above; the first and the fourth stout and tuberculate, the fourth being mesad of the base of the antennae; the second, third and fifth pairs small and the third located a little caudad and the fifth anterior to the fourth pair. The tip of the snout extends upto mid-coxae. A pair of geniculate antennae present. Pronotum elongate, anterior margin and the basal angles rounded, bears dorsally six pairs of tuberculate setae. The anterior four pairs are in a circle in the anterior half of the pronotum; the other two pairs more posterolateral, of which the anterior pair shorter than the posterior. A pair of prominent spiracles located laterally at the posterior end of prothorax. Mesonotum with a pair of tiny setae, each seta being located on either side of the mid-dorsal line. Metathorax with three pairs of setae arranged in a row, of which one submedian,

**Fig. 18** : Semidiagrammatic sketch of pupa of  
**C. sordidus**

- a** = Dorsal view
- b** = Lateral view showing the location  
of spiracle
- c** = Ventral view

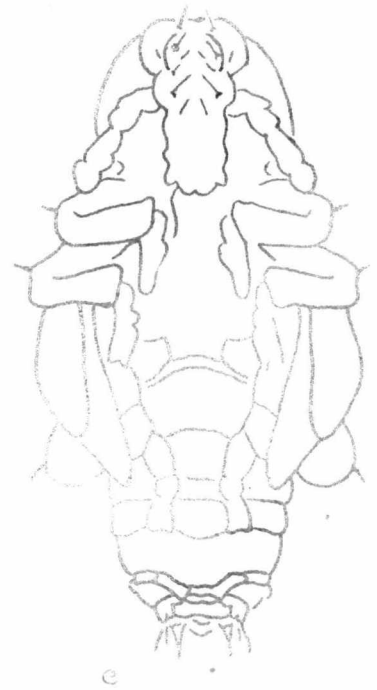
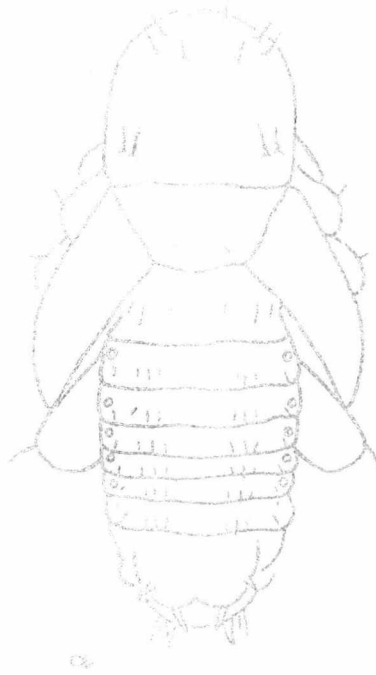


Fig. 18.

tiny and the other two dorsolateral, mesad of which is more prominent.

Legs closely appressed to the ventral body, each leg with a lateral seta close to the distal end of the femur. Wing pads closely appressed to the body, partly concealing the legs and extends upto 5th or 6th abdominal segments.

First six abdominal segments normal, each with four pairs of setae, arranged on the mediodorsal transverse ridge. There are five pairs of spiracles well raised from the general surface of the body on the first five abdominal segments. The sixth pair indistinct. Segments 7th to 10th fused and segments 8th to 10th more ventral. The dorsum of the 7th segment with two pairs of setae located posteriorly of which the inner pair stouter and longer. Two prominent spines situated ventrally on the 9th segment with a pair of smaller setae at the base of each spine.

On an average pupa measures 11.45 mm in length and 3.90 mm in breadth, with a minimum of 11.00 mm and a maximum of 12.50 mm for length and breadth varied from 3.50 to 4.00 mm (Table IV).

e. Adult (Fig. 19) :

The adult at first soft, light-brown, gradually becomes

Fig. 19 : Adult of C. sordidus



Fig.19

deep brown, finally turning uniform jet black. It measures on an average 12.55 mm in length and 3.75 mm in breadth (Table IV). The body divisions, head, thorax and abdomen clear. The female stouter than male.

Head : Small, spherical, retractile and can be partially withdrawn into the socket-like anterior part of prothorax. Snout slightly curved and directed ventrally, basal half finely punctate and thicker than the sparse and finely punctated apical half. On an average the snout measures 2.84 mm in length. A pair of ventral scrobes from the centre of which the antennae arise present on the basal thickened part of the snout. Two prominent, blackish, shining compound eyes protruding above the surface. Antennae geniculate (Fig. 20) with a conspicuously longer scape; pedicel which forms the pivot between the scape and flagellum is more or less equal in length to first flagellar segment. The flagellum consists of six segments, closely approximated, with the segments 2 to 5 almost equal and shorter than the first, and the last being very much enlarged and clubbed; the club single segmented; proximal two-third gradually widening from base and the surface marked with zig-zag striations and the distal part tapering to a bluntly rounded point and densely covered with short, fine setae. Proximal part with a circle of six stout setae.

Fig. 20 : Antenna of adult C. sordidus

c = Club  
F = Funicle  
P = Pedicel  
S = Scape  
s = Seta on club

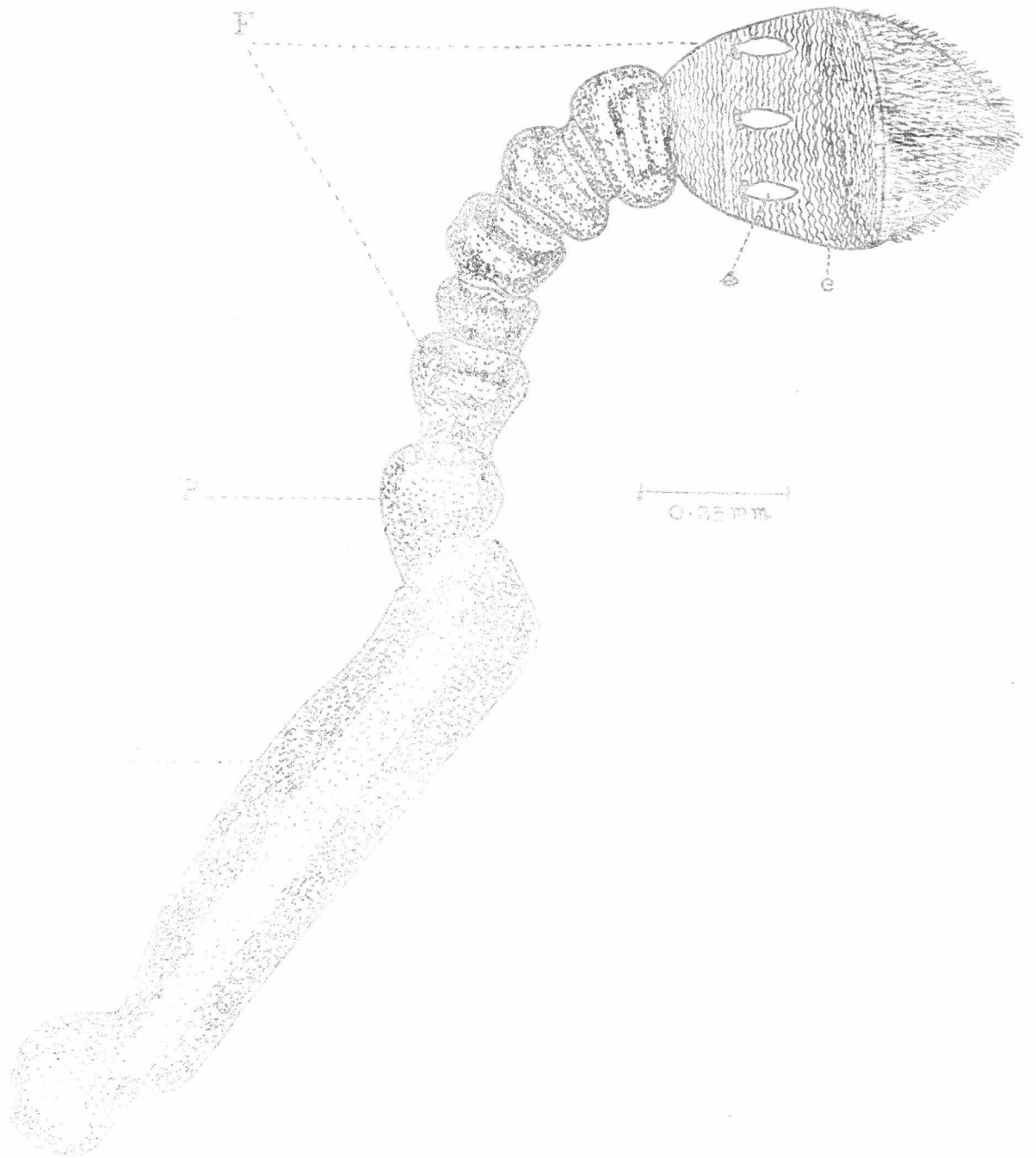


Fig. 20.

The mouthparts biting and chewing type and concealed within the distal tip of the snout except for the terminal ends of mandibles and maxillae. Clypeus indistinct. Labrum simple, flap-like piece, wider than long, sub-rectangular (Fig. 21). Dorsally smooth, ventrally with a horizontal row of spines located towards the anterior margin.

Mandible (Fig. 22). Two, prominent, well developed, heavily sclerotised, roughly triangular with four pointed denticles arranged in semicircle, curved ventrally; fourth denticle from the dorsal short; middle two denticles wide and stout. Molar area not so prominent. Surface of mandible smooth. Mandible provided with a 'Pharyngeal bracon' which is fleshy, long and with fleshy stout hairs, measuring on an average 1.94 mm in length.

The two maxillae (Fig. 23) distinct, located in deep clefts (Fig. 24) at the distal end of the snout ventrally, one on either side of the labium hardly projecting out of these clefts in the snout. Each maxilla consists of an elongate, basal cardo and a small, rectangular stipes which is much shorter than the cardo. The maxillary palp borne at the distal end of palpiger and almost as long as the cardo, three segmented and gently tapering towards the distal end. Third segment more or less conical with a number of sensory pegs at the distal end. Lacinia and galea fused together to

Fig. 21 : Labrum of adult C. sordidus

Fig. 22 : Mandible of adult C. sordidus

md = Mandible

phb = Pharyngeal bracon

Fig. 23 : Maxilla of adult C. sordidus

C = Cardo

hma = Hair of mala

MxP = Maxillary palp

S = Stipes

tma = Teeth of mala

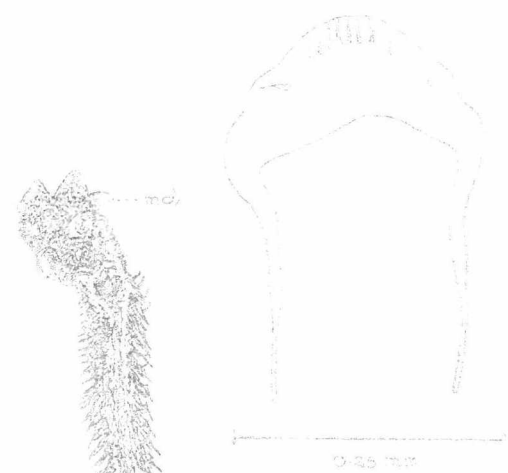


Fig. 21.



Fig. 22.



Fig. 23.

form a wide mala; the mala bears mesally a number of stout finger-like processes in two series, the ones in one series being narrower than those in the other. In addition innumerable longer bushy hairs are present on the mesal surface of the mala.

Labium (Fig. 25) located ventrally. It appears like a flap, broadly rounded at the distal end. The inner face appears to have a median wide furrow the edges of which have a number of long hairs more particularly towards the posterior end. No palpi are seen.

Prothorax long, evenly punctate, constricted near the head to form a narrow collar. Sides almost parallel posteriorly from the middle, and gradually tapering to the anterior constriction. Meso- and metathorax fused to form pterothorax, which is shorter dorsally than the prothorax. Each of the thoracic segments with a pair of stout cursorial legs (Fig. 26). Each leg consists of coxa, trochanter, femur, tibia, tarsus and a pair of claws. Coxae more or less globular, trochanter small. Femur laterally compressed and gradually widening towards apex, emarginate apically and bilobed forming a groove for the insertion of tibia. Tibia moderately straight, grooved beneath, provided with a row of setae on either side of the groove, apically curved terminating in a strong hook. Tarsus four-segmented, first

Fig. 24 : Snout tip of adult C. sordidus showing the location of mandibles and maxillae

Lbm = Labium  
Md = Mandible  
Mx = Maxilla

Fig. 25 : Labium of adult C. sordidus



Fig. 24



Fig. 25

Fig. 26 : Leg of adult C. sordidus

C = Coxa  
Cl = Claws  
F = Femur  
Ta = Tarsus  
Ti = Tibia  
Tr = Trochanter



segment long, wide at apex; second a little longer than broad; third slightly shorter than first and broader at apex, emarginate for reception of fourth which is elongate, curved, sub-cylindrical, armed with two curved divergent claws.

The pterothoracic segments bear each on its dorso-lateral margins, a pair of wings. The elytra (Fig. 27) highly sclerotised and held above the hind wings. Elytra do not cover the last abdominal segment (pygidium). Elytron elongate, sub-ellipsoidal, convex with nine longitudinal striations, the more anterior one of which confined to only basal half; all having punctations arranged more or less at regular intervals. Hind wings (Fig. 28) membranous, hyaline, veins light brown. The hind wing longer than forewing and kept folded beneath the elytron. Costa conspicuous only at base. The subcosta starts behind the costa and terminally fuses with the radius, which appears to have a common origin with the subcosta and joins with the latter terminally. Radius runs upto the apical margin and not very clear beyond the fusion with subcosta. The median vein lies behind, longest of all the veins and faint. Cubitus thick, starts behind radius, ends abruptly in the middle; anal veins represented by two faint veins.

Fig. 27 : Elytron of C. sordidus

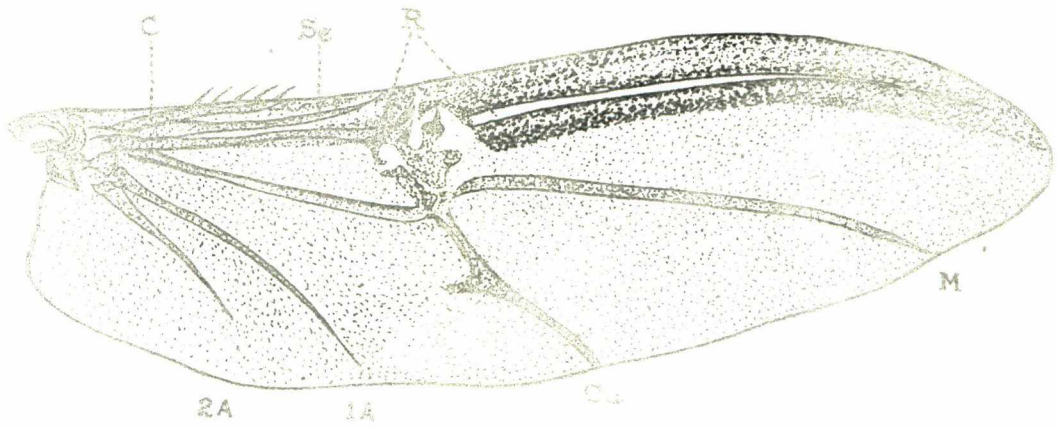
Fig. 28 : Hind wing of C. sordidus

1A,2A	=	Anal veins
C	=	Costa
Cu	=	Cubitus
M	=	Median vein
R	=	Radius
Sc	=	Subcosta



186

Fig. 27.



186

Fig. 28.

Abdomen sub-conical, with seven tergites, and five sternites visible ventrally. Sternites sparsely punctate, tergites smooth. First two abdominal sternites connate at middle. Third and fourth sternites together about as long as second, fifth sternite longer and curved ventrally. Pygidium almost vertical and exposed, beyond the apices of the elytra; surface punctate and pubescent. Abdomen and thorax ventrally punctate.

Male with first abdominal sternite depressed along the mid-ventral line, while in female it is flat or convex.

## B. BIOLOGY

### 1. Distribution

Observations made in banana growing areas of Karnataka for the incidence of the banana rhizome weevil revealed that it occurred in the following places:

	<u>District</u>	<u>Locality</u>
1)	Bangalore	Hebbal Channapatna Anekal
2)	Kolar	Srinivasapura

	<u>District</u>	<u>Locality</u>
3)	Mandya	Mandya Maddur
4)	Mysore	Mysore Nanjangud
5)	Coorg	Mercara
6)	Hassan	Channarayapatna Holenarsipur
7)	South Kanara	Mangalore
8)	North Kanara	Sirsi
9)	Chikkamagalur	Chikkamagalur Balehonnur
10)	Shimoga	Sagar Thirthahalli
11)	Dharwar	Dharwar Manoli
12)	Belgaum	Bailhongal
13)	Bellary	Hospet
14)	Chitradurga	Davangere Beemasamudra
15)	Tumkur	Tumkur Gubbi

Intensity of infestation is given in the map, (Fig. 29). The pest was severe only in Mysore District.

2. Economic importance :

As observed in Mysore district, this insect is an economically important pest of banana, occurring invariably in all the seasons through-out the year.

The damage was caused by both adults and grubs. Observation made on the incidence of the pest at Devarasanahally and Nanjangud, Mysore District revealed that 80 to 90 per cent of banana plants were infested in the field. Due to this the yield was considerably less and the economy of the cultivators was directly affected.

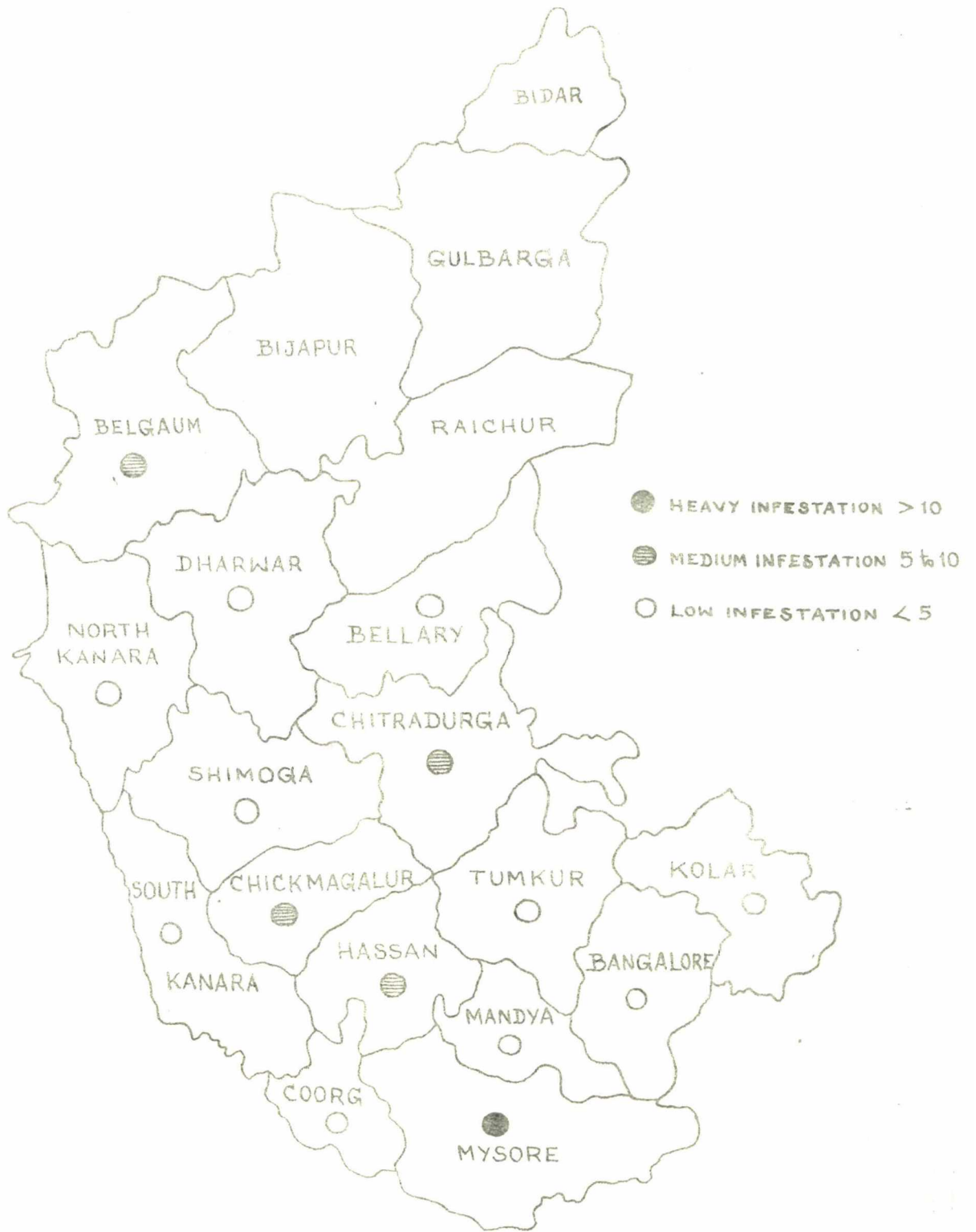
3. Life cycle :

The life cycle of the pest was studied in the laboratory through six generations following the technique already described under material and methods.

a. Egg :

The female weevil selected a suitable place on the pseudostem or rhizome, made a hole measuring on an average 0.76 mm in diameter with the help of the snout, then turned

Fig. 29 : Incidence of C. sordidus in Karnataka



INCIDENCE OF *C. sordidus* (GERMAR) IN KARNATAKA

Fig. 29.

around and deposited an egg. Under field conditions, the eggs were observed on the pseudostem to a height of 25 to 30 cm from the surface of the soil. Eggs were more on the outer leaf sheath of the pseudostem. When the infestation was more, the adults entered the rhizome and pseudostem through the riddles caused by the grubs and here the eggs were laid freely without being inserted into the tissue and also in the decaying leaf sheaths and rhizomes. The incubation period varied from 5 to 10 days (average, 6.87 days) (Table VI). The grub cut the chorion at the apical end of the egg and came out leaving thin chorion behind. The entire process took 5 to 6 minutes. Under laboratory conditions hatching was observed both during day and night. Cent per cent hatching was observed in the laboratory except during the months of October to January when the percentage ranged from 44.30 to 90.00 (Table VI).

b. Grub :

The larval period was completed in seven instars (Fig. 30) with seven moults. During each moult the head capsule ruptured along the epicranial suture followed by the rupture of the thoracic integument. In the freshly moulted grub the head was white in color except the mandibles which were brown. Later the head also turned brown.

Table VI

Incubation period (in days) of eggs of C. sordidus during different months

MONTHS	MINIMUM	MAXIMUM	AVERAGE	% HATCHING
Aug. '72	5	8	6.4	100.0
Sept.	6	7	6.5	100.0
Oct.	8	8	8.0	75.0
Nov.	8	10	9.0	44.3
Dec.	9	10	9.5	52.0
Jan. '73	7	9	7.6	90.0
Feb.	7	7	7.0	100.0
Mar.	6	7	6.3	100.0
Apr.	5	6	5.4	100.0
May	6	7	6.2	100.0
Jun	6	7	6.6	100.0
Jul.	5	7	6.3	100.0

The duration of different instars was 3 to 5 days for I instar; 5 to 7 days for II instar; 5 to 7 days for III instar; 5 to 7 days for IV instar; 5 to 8 days for V instar; 5 to 7 days for VI instar; and 6 to 8 days for VII instar (Table VII).

The first instar grub immediately after emergence started boring into the leaf sheath or rhizome. The grub bored in a linear and irregular way downwards (Fig.31). This tendency was well pronounced in the first instar grub. The resulting tunnel was then filled up with brownish or pale white excreta. After reaching the rhizome, the grubs had the tendency to restrict their tunnelling activity to the rhizome alone. When the rhizome became unfit for feeding, the grubs moved to the pseudostem. This habit was noticed occasionally. If and when the side suckers came up, instead of moving to the pseudostem they made their way to the suckers. Nearing pupation the grub moved to the periphery of the rhizome, where it excavated a cavity (Fig.32) in the host tissue for pupation. This cavity was normally found at the end of the tunnel with a few strands of fibre at the tunnel end. When the infestation was heavy, the pupal cell was found constructed even in the pseudostem also which was invariably found lined with fibrous material.

**Table VII**  
**Duration of different life stages of Cosmopolites sordidus during different months**  
**( in days )**

Seasons	Incubation period		Average larval period						Total Prepupa	Pupa	Total life cycle (egg to adult)							
	Min.	Max.	Ave.	I	II	III	IV	V				VI	VII	Min.	Max.	Ave		
Jan. '72 to Mar. '72	7	9	7.6	4.4	5.4	5.8	6.1	5.9	6.0	6.7	40.3	2	3	2.5	6	8	7.2	57.6
Mar. to May '72	6	7	6.2	4.2	5.8	6.2	5.7	6.0	6.5	6.7	41.1	2	3	2.7	6	7	6.5	56.5
May to July '72	6	7	6.2	4.3	5.3	5.8	5.6	5.6	5.5	6.3	38.4	2	3	2.4	6	7	6.5	53.5
July to Sept '72	5	7	6.0	3.7	5.2	5.2	5.1	5.3	5.4	6.7	36.6	2	3	2.6	6	7	6.4	51.6
Sept. to Nov. '72	6	7	6.3	3.5	5.7	5.7	5.5	5.9	5.6	6.7	38.6	2	3	2.7	6	8	7.5	55.1
Nov. to Feb. '73	8	10	8.9	4.5	6.3	6.2	6.6	6.8	6.4	7.6	44.4	3	3	3.0	6	11	8.8	65.5

Fig. 30 : Larval instars of C. sordidus

Fig. 31 : Damage to the outer leaf sheath of banana pseudostem by first instar grub of C. sordidus

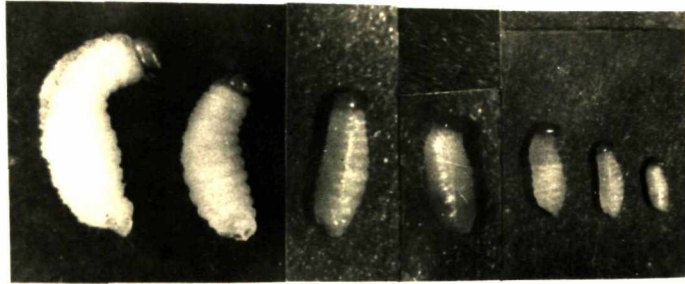


Fig.30



Fig.31

Total larval period ranged from 36 to 46 days (average, 39.9 days).

c. Prepupa :

At this stage the larva stayed comatose in the pupal cavity. The prepupa exhibited linear rotary movements in the cavity. The period lasted for 2 to 3 days (Table VII). The last moult took place at this stage. Ecdysis occurred by the rupturing of head capsule along the ecdysial suture and the thoracic integument along the mid dorsal line.

d. Pupa : (Fig. 33)

The pupal period occupied on an average 7.15 days with a minimum of 6 and a maximum of 10 days (in November). Pupa exhibited rotary movements of the abdomen when disturbed. The pupal period was more during October to February (7.2 to 8.8 days), while the duration during the other months (March to September) varied from 6.4 to 6.5 days (Table VII).

At the time of emergence of the adult, the pupal skin split upto thoracic region along the mid-dorsal line. During this period the insect made frequent movements of legs and thus pushed the pupal skin posteriorly which in

**Fig. 32** : Pupal cavity of C. sordidus in rhizome

**Fig. 33** : Pupa of C. sordidus

- a = Dorsal view
- b = Ventral view
- c = Lateral view



Fig.32



a



b



c

Fig.33

many cases was found at the tunnel end of the pupal cavity. During this process the snout came out first followed by legs and rest of the body. Adult emergence was usually during night times.

e. Adult :

The newly emerged adult remained in the pupal chamber for 2 to 4 days till the body hardened. Later the adult made a hole on the rhizome and came out. The total life cycle from egg to adult ranged from 50 to 70 days with an average of 56.63 days.

i. Food : Soon after emergence from the rhizome, the weevils crawled on to the soil surface and from there entered the leafsheaths during night and fed upon the material found inbetween the two epidermal layers of leaf sheath. The adults were also found to feed on rhizome. The details of the damage caused by the adults have been described elsewhere.

ii. Activity and habits : In general the adults were found to be active only during the night. During day time they hid themselves beneath the pseudostem or rhizome in the laboratory and in the field majority of them would be inbetween the two epidermal layers of the leaf sheaths and

sometimes inbetween rhizome and soil. Adults were always found in places where the humidity was high. They were always shining black with a film of moisture on their body. The same was observed in the laboratory also but when the adults were removed and placed away from moisture, they became dull black with a greyish encrustation above their body. In severely infested fields adults were found deep in the rhizome in larval funnels and also in the centre of the pseudostem to a height of about 60 to 75 cm above the soil surface. Adults feigned death when disturbed. In the laboratory egg laying was seen during night more on the exposed cut surface of the pseudostem rather than the cut surface which was close to the soil and they very rarely came on to the exposed cut surface of the pseudostem during day time. In the field adults were collected regularly to the bait traps which were placed during the evening and observed the next morning and no adults were collected during day time.

In the laboratory the adult weevils were noticed during night to walk with the head carried slightly above the level of the body at an angle with antennae outstretched laterally and they feigned death when disturbed. Similar observations were made in the field also. During the process of feigning death the scope got lodged in the scrobe and the flagellum also got folded. The insect was *not seen* flying

at anytime under field conditions. All experiments conducted in the laboratory except one proved negative for the flying capacity of the insect, but in one experiment where the adult weevils were hung in the incubator by means of threads fixed on to their pronotum with the help of wax, where the temperature of the incubator was maintained at 35°C and at a relative humidity of 65 to 70 per cent, the weevils opened their wings. Other than this observation flying was not observed either in field or in laboratory during the studies.

iii. Copulation and oviposition : Weevils copulated freely both in the field as well as in the laboratory between 6.30 to 8.00 p.m. However, mating was observed during the day time when the weevils were released on to the fresh food source. Copulation took place 10 to 15 days after emergence, and lasted for 4 to 5 minutes and then the males and females got separated. During copulation, the male mounted over the female from behind and rested at an angle of about 45° over the female weevil taking firm hold of the female with the help of meso and metathoracic legs while the prothoracic legs were used to adjust the body movements to reach the female genital opening.

Pre-oviposition period varied from 15 to 28 days

with an average of 20.5 days (Table VIII). Oviposition took place during night time. However, very few eggs were collected during day time in the laboratory. A fertilised female weevil during the life time laid 36 to 53 eggs (average, 45.9 eggs) (Table VIII). The oviposition period varied from 313 to 556 days with an average of 471.7 days. The maximum egg laying was noticed during the 7th month (Fig. 34). The post oviposition period of adult female varied from 14 to 57 days with an average of 35.4 days (Table VIII).

iv. Longevity : The longevity of males and females was more or less same. The adults reared in the laboratory from field collected final instar grubs survived for 546 to 582 days with an average of 564.5 days, while the individuals reared in the laboratory survived for 369 to 443 days with an average of 424.5 days (Table IX).

Another experiment conducted to study the survival capacity of the adults of C. sordidus with and without food under dry and wet soil conditions in the laboratory revealed that they survived for a minimum period of 348 days and a maximum period of 421 days (average, 387.00 days) with food and for a minimum period of 98 days and a maximum period of

Table VIII

Pre-oviposition, oviposition and post-oviposition period,  
and fecundity of C. sordidus

(in days)

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	Minimum	Maximum	Average
Pre-oviposition	15	28	20.5
Oviposition	313	556	471.7
Post-oviposition	14	57	35.4
Fecundity	36 eggs	53 eggs	45.9 eggs

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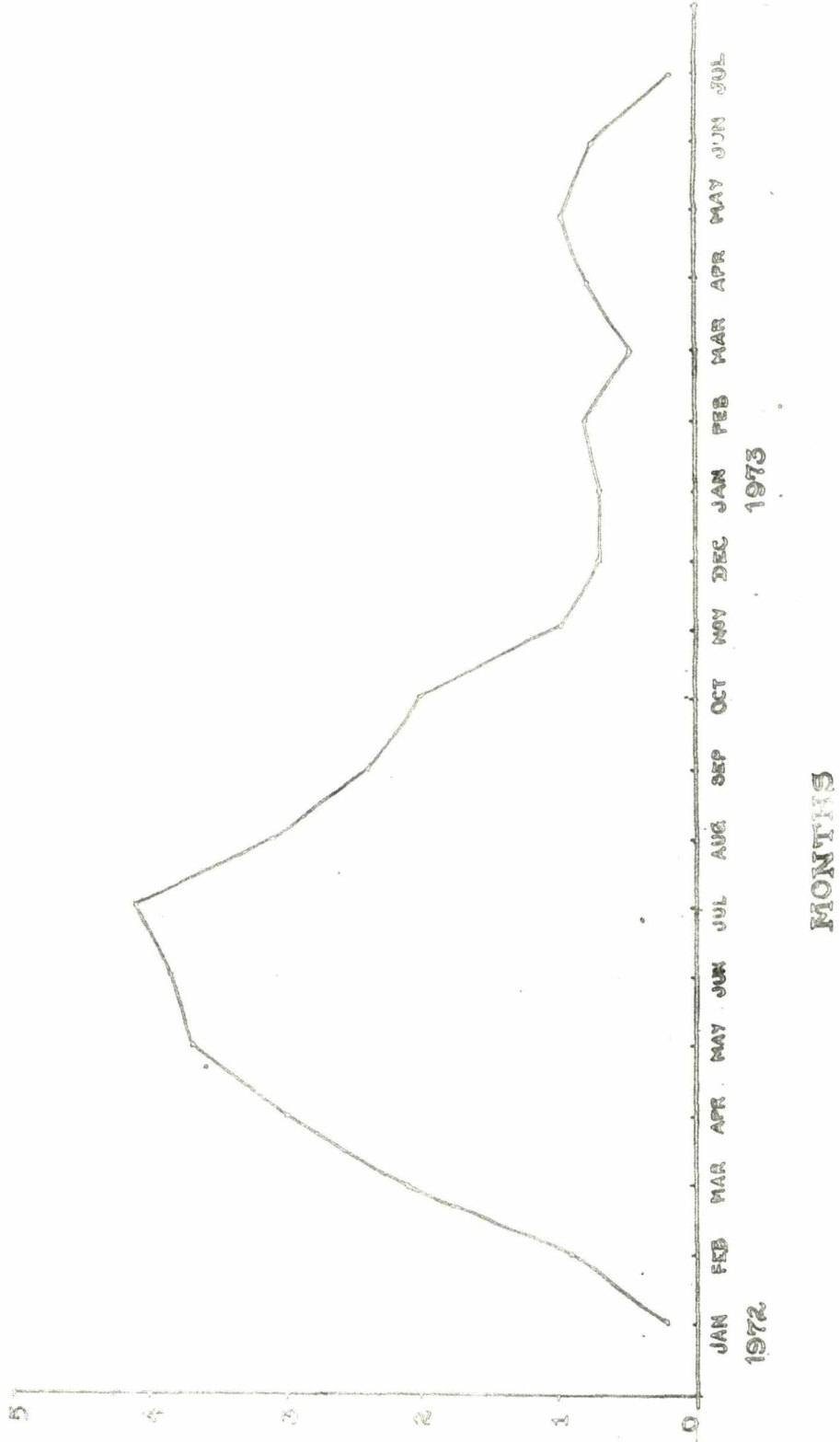


Fig. 34. FECUNDITY OF COSMOPOLITES SORDIDUS DURING DIFFERENT MONTHS.

Table IX

Longevity and sex ratio of C. sordidus

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Insects	Sex ratio ( ♀ to ♂ )	Longevity (in days)		
		Minimum	Maximum	Average
Field collected	1 : 1.4	546	582	564.5
Laboratory reared	1 : 1.2	369	443	424.5

---

128 days (average, 111.96 days) without food under wet soil condition. Under dry soil condition the adults lived for a minimum period of 12 days and a maximum period of 18 days (average, 14.24 days) with food and for a minimum period of 8 days and a maximum period of 14 days (average, 9.96 days) without food (Table X).

v. Sex ratio : The sex ratio of the weevils was determined from several samples collected at random from the field and also from weevils reared under laboratory conditions. In both the cases the population of males was more (Field collected adults, 1:1.4; laboratory reared individuals, 1:1.2) (Table IX).

vi. Seasonal incidence : In order to know the seasonal incidence of banana rhizome weevil, a study was conducted from September, 1971 to September, 1973 covering 24 months continuously. The data on adult weevils attracted to rhizome in different months during 1971, 1972 and 1973 are presented (Table XI). The study revealed that the incidence was minimum during the months of November, December and January. The number of adult weevils attracted gradually increased from January to June and reached the peak during the month of July. Again there was a steep fall in attraction from July to November (Fig. 35).

Table X

Survival capacity of the adults of Cosmopolites sordidus with and without food under dry and wet soil conditions (in days)

	With food		Without food	
	Minimum	Maximum Average	Minimum	Maximum Average
Wet soil	348	421 387.00	98	128 11.96
Dry soil	12	18 14.24	8	14 9.96

Table XI

Seasonal incidence of Cosmopolites sordidus during 1971 to  
1973

Months	Number of adults attracted to traps		
	1971	1972	1973
Jan.	-	73	74
Feb.	-	88	87
Mar.	-	128	114
Apr.	-	148	147
May	-	175	178
Jun.	-	203	205
Jul.	-	221	220
Aug.	-	194	185
Sep.	166	163	172
Oct.	199	128	-
Nov.	64	89	-
Dec.	65	73	-

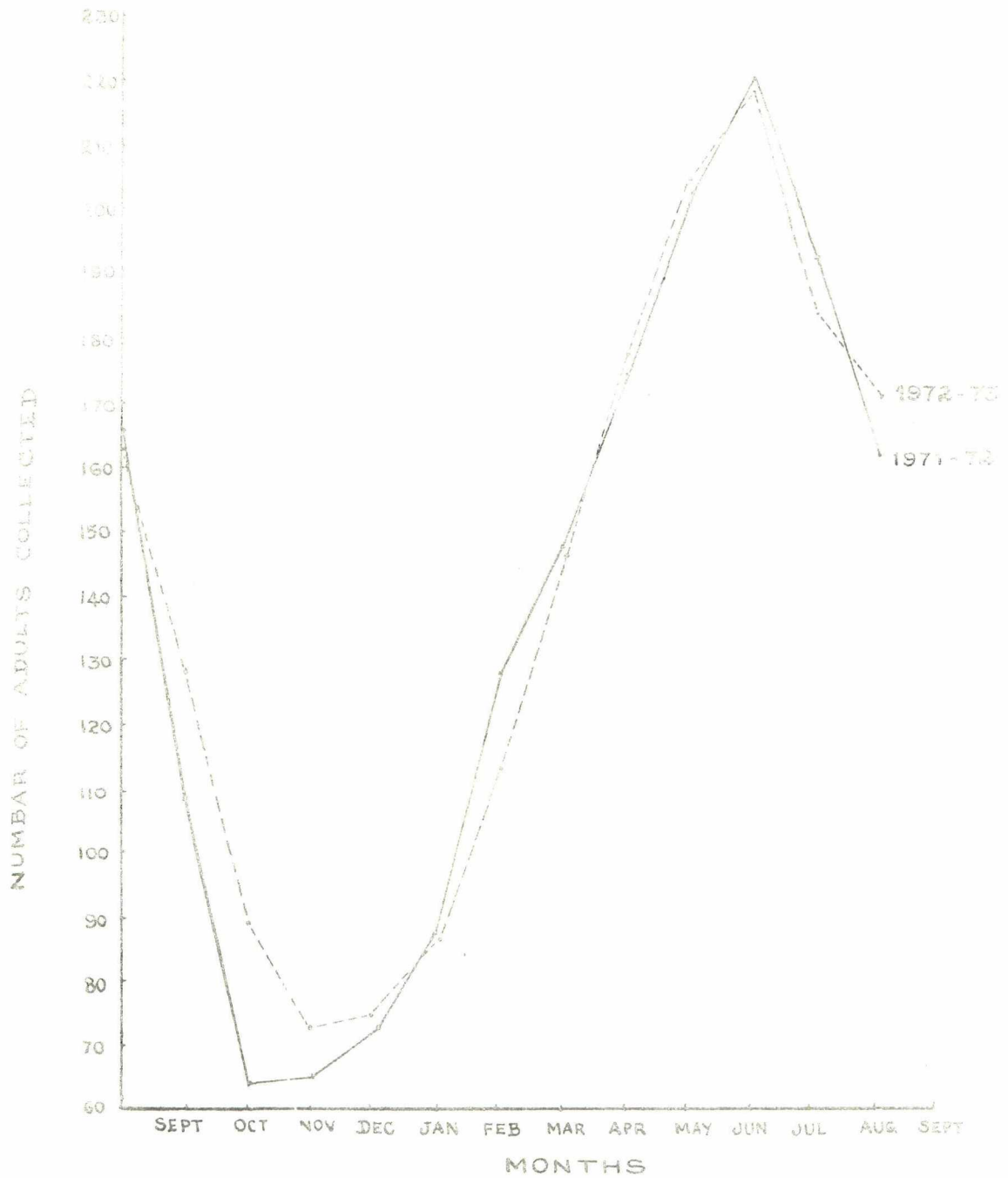


Fig.35. SEASONAL INCIDENCE OF BANANA RHIZOME WEEVIL

f. Number of generations :

To determine the number of generations completed by the weevil, studies were made starting from January, 1972 and extending upto February, 1973. The insect completed 5 generations during this period under laboratory conditions. However, under field conditions overlapping of generations was noticed owing to the fact that the oviposition period ranged from 313 to 556 days, so much so all stages of the pest were seen at any time of the year.

g. Route and mode of infestation :

The initial infestation was always through the infested suckers being carried from infested plantation to new plantation. In the early stage the infestation was almost localised. When once the weevil gained entry into a stool, it fed and multiplied on the same stool and remained till the stool was destroyed to a stage of not providing any more food. At this stage the weevils started migrating and reaching the nearest stool and then breeding continued and thus the infestation gradually spread to the entire field in irregular patches.

h. Nature of damage :

The insect damaged the plants both in its adult

and larval stages. The adults fed by scraping the tissue inbetween the two layers of epidermis of the outer leaf sheath, which gradually decayed, and the portion above the site of feeding dried gradually. This damage was usually confined to the outer leaf sheaths, and in severe cases the adults were even found in the centre of the pseudo-stems. The adults also made small punctures at the base of the leaf sheaths near the ground level for feeding and oviposition. They also fed on rhizome.

Grubs after hatching bored through the leaf sheath in a linear way (Fig. 31) and then into the rhizomes and fed on the internal tissue. At first the grub tunnelled downwards in the peripheral region of the rhizome at the root base damaging the basal part of the roots. After some-time, it started tunnelling towards the growing point. Towards the end of its larval life, it tunnelled towards the outer margin of the rhizome. As the grub bored, it packed the tunnels with frass. The size of the tunnel increased with the increase in the size of the grub. In plants where many eggs were laid, the resulting grubs bored together resulting in complete riddling of the tissue (Fig. 36) and reducing it into a felty mass (Fig. 37).

The external symptom produced due to the attack

**Fig. 36** : Riddling of the tissue of banana rhizome by  
the grubs of C. sordidus

**Fig. 37** : Banana rhizome reduced into a fatty  
mess due to the heavy attack by  
larvae of C. sordidus

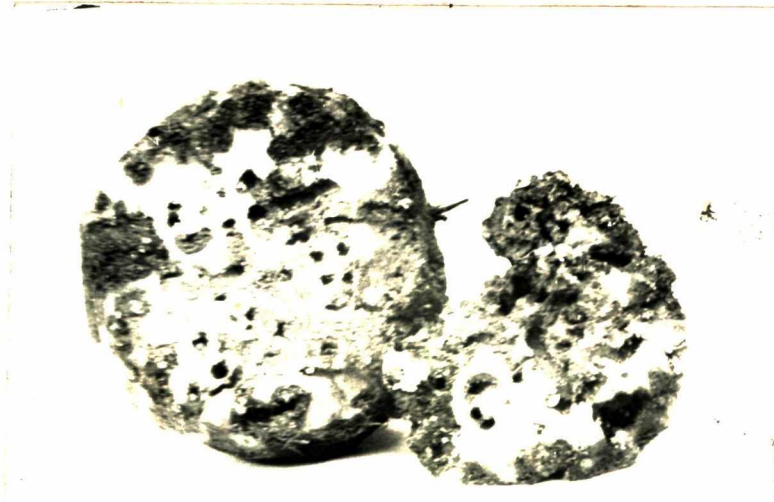


Fig.36



Fig.37

by the grubs was the typical marginal drying of outer leaves which gradually extended to the inner leaves (Fig. 38) and later the outer leaves dried up completely. In severe cases, where the growing point was affected, dead heart was observed both on the main as well as on the young suckers (Fig. 39). Plants which have overcome this damage produced a smaller bunch with less number of hands and small fingers (Fig. 40). Still some other plants snapped just above the rhizome when pushed. Dead heart was observed even when one grub was present (here all the outer leaves were normal) (Fig. 41), due to the fact that the growing point was damaged.

Other observations made were, that the infestation was severe in old and neglected plantations compared to new plantations. Infestation was much severe in plantations where lot of weed growth was present (Fig. 42). Here the plants were very weak and tapering towards the top and the damage was seen upto a height of 75 to 90 cm above the ground level (Fig. 43).

1. Host range :

The insect was not found to feed and breed on any host other than Musa spp.

**Fig. 38** : Marginal drying of outer leaves and  
dead heart in the sucker of banana  
plant due to C. sordidus

**Fig. 39** : Dead heart on banana sucker caused by  
C. sordidus



Fig.38



Fig.39

**Fig. 40 : Banana bunch with less number of hands  
and small fingers caused by C. sordidus**

**Fig. 41 : Dead heart on banana plant caused by  
a single grub of C. sordidus**



Fig.40



Fig.41

**Fig. 42** : Banana plantation with heavy weed growth  
and severe infestation of C. sordidus

**Fig. 43** : Banana pseudostem damaged by grubs of  
C. sordidus to a height of 75 to 90 cm



Fig.42



Fig.43

The adult weevils did not survive and breed on any of the hosts tested, namely, elephant foot, sweet potato, potato, canna and tapioca though the experiment was continued for three months. Similarly the grubs also did not feed and develop even-though they were released into the holes artificially bored, on the above hosts. The grubs pushed their way out and dropped to the soil and died.

C. VARIETAL RESPONSE OF BANANA TO THE DEVELOPMENT OF  
C. SORDIDUS

Fifteen varieties of banana representing the major genomic groups under the family Musaceae collected from Pineapple and Banana research station, Trichur, Kerala were screened for their resistance to C. sordidus by releasing twentyfive adult weevils, one month after planting, for each plant. The number of immature stages, viz., grubs, prepupae and pupae present in the uprooted rhizomes was counted three months after planting and the degree of susceptibility was determined.

The number of immature stages ranged from 2.67 being lowest in Lacatan to 32.00 being the highest in Maduranga (Table XII). Maduranga recorded significantly the highest number of immature stages over all the varieties. Peykunnan

Table XII

Number of immature stages of C. sordidus collected from  
different varieties of banana

S.No.	Vardety	R.I	R.II	R.III	Total	Mean
1	Rasabale	7	5	5	17	5.67
2	Poovan	4	4	5	13	4.33
3	Nendran	8	4	7	19	6.33
4	Sirumali	7	6	6	19	6.33
5	Virupakshi	6	4	4	14	4.67
6	Nallabontha	12	15	13	40	13.33
7	Budubale	16	15	18	49	16.33
8	Penkunnan	21	18	29	68	22.67
9	Maduranga	31	34	31	96	32.00
10	Cavendish(R)	4	3	4	11	3.67
11	Cavendish(D)	4	2	4	10	3.33
12	Lacatan	2	2	4	8	2.67
13	Neypoovan	8	4	10	22	7.33
14	<u>M. acuminata</u>	6	6	7	18	6.00
15	<u>M. balbisiana</u>	3	3	4	10	3.33

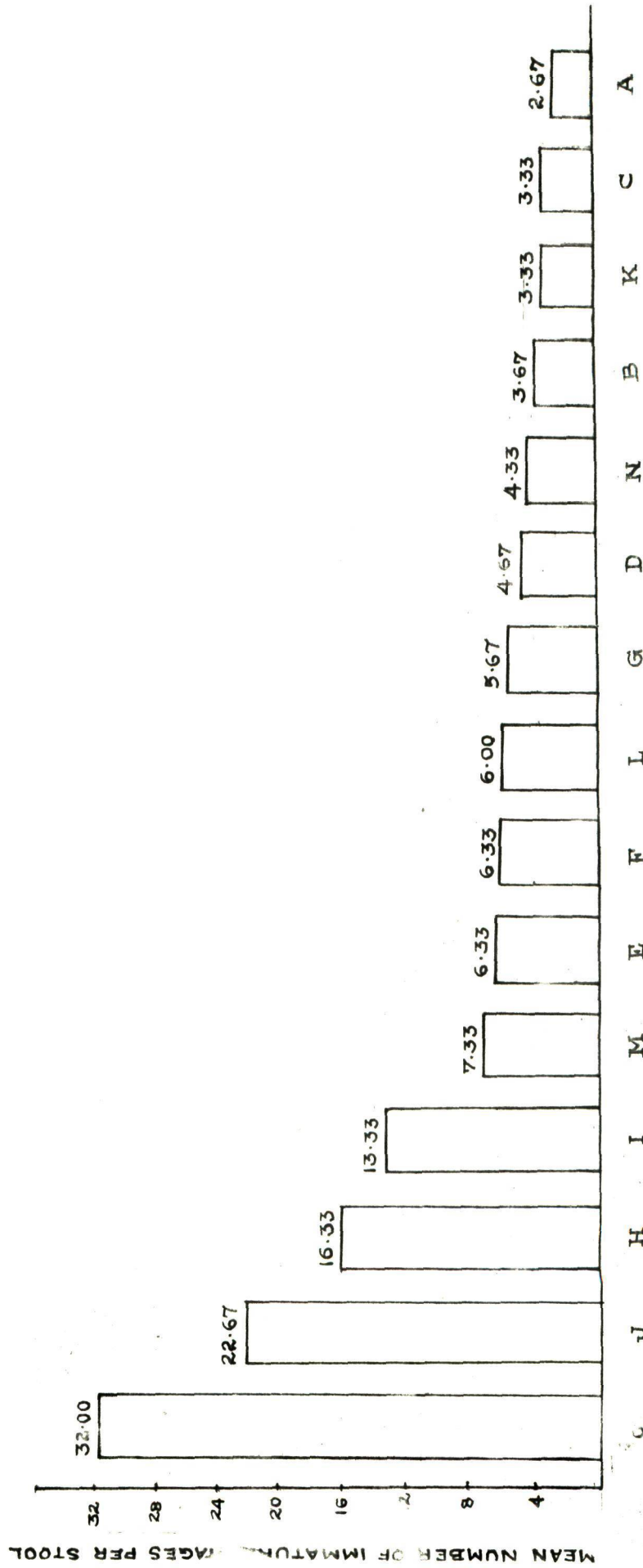
S.E. 0.219

C.D. 0.45 at 5 percent level  
0.61 at 1 percent level

(22.67) also recorded significantly higher number of immature stages as compared to other varieties. Next in order were Budubale (16.33) and Nallabontha (13.33) which also showed significantly higher number of immature stages over other remaining varieties and showed no significant difference between them. The varieties Lacatan, Cavendish (D) (3.33), Musa balbisiana (3.33), Cavendish (R) (3.67), Poovan (4.33) and Virupakshi (4.67) recorded lowest number of immature stages ranging from 2.67 to 4.67 and significantly differed from Musa acuminata (6.00), Nendran (6.33), Sirumali (6.33), Neypoovan (7.33) which were on par with one another. Again there was no significant difference among Musa acuminata, Nendran, Sirumali and Neypoovan. Rasabale (5.67) was on par with all the varieties except with Nallabontha, Budubale, Peykunnan and Maduranga (Fig. 44).

#### D. CHEMICAL CONTROL OF C. SORDIDUS BY USING GRANULAR SOIL INSECTICIDES

A randomised block design with six replications was laid out with a view to study the efficacy of four granular soil insecticides, viz., carbofuran, phorate, disulfoton and quinalphos each at 1 gm a.i. per plant for the control of C. sordidus on the banana variety Budubale. At the time of



VARIETIES

Fig. 44. VARIETAL RESPONSE OF BANANA TO COSMOPOLITES SORDIDUS.

planting the suckers, twentyfive adult weevils were released for each plant and the above insecticides were applied to the soil around plant a month after planting. The rhizomes were uprooted a month after the application of insecticides and the number of immature stages and adult weevils were counted in all the treatments including control.

All the insecticidal treatments showed significantly less number of immature stages as compared to untreated control.

The number of immature stages in the insecticidal treatments varied from 3.33 being lowest in phorate to 11.33 being highest in quinalphos as compared to 23.50 in untreated control (Fig. 45). Among the insecticidal treatments phorate showed significantly less number of immature stages as compared to disulfoton (7.83) at 5 per cent level of significance and quinalphos at both the levels of significance. Carbofuran (4.33) showed significantly less number of immature stages as compared to quinalphos at both levels of significance. There was no significant difference between phorate and carbofuran, carbofuran and disulfoton, and disulfoton and quinalphos (Table XIII).

The number of adults recovered in all the insecticidal treatments were significantly less as compared to

Table XIII

Number of immature stages of C. sordidus recovered in different insecticidal treatments and control 30 days after treatment

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Treatment	R-I	R-II	R-III	R-IV	R-V	R-VI	Total	Mean
Control	23	25	32	26	22	13	141	23.50
Carbofuran	3	4	5	5	5	4	26	4.33
Disulfoton	4	6	8	9	14	6	47	7.83
Phorate	3	3	4	3	4	3	20	3.33
Quinalphos	12	13	10	8	14	11	68	11.33

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S.E. 0.239

C.D 0.56 at 5 per cent level

0.74 at 1 per cent level

Table XIV

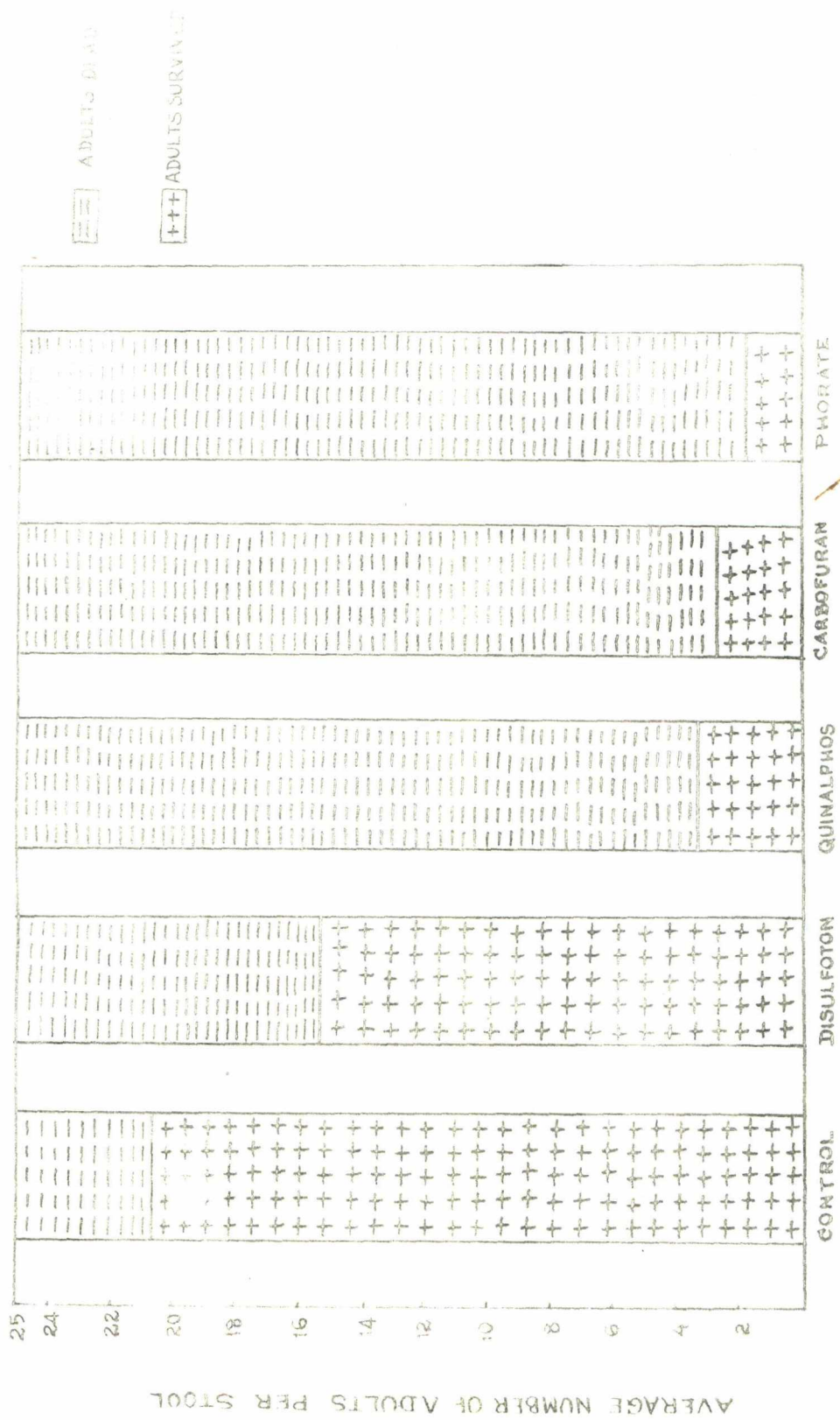
Number of adults of C. sordidus recovered from different treatments

Treatment	(Survival of adults 30 days after treatment)						Total	Mean
	R-I	R-II	R-III	R-IV	R-V	R-VI		
Control	23	20	22	22	18	19	124	20.67
Carbofuran	3	3	4	2	1	3	16	2.67
Quinalphos	3	6	2	2	3	4	20	3.33
Disulfoton	18	12	18	15	12	17	92	15.33
Phorate	2	3	1	2	2	1	11	1.83

S.E. 0.985

C.D. : 2.05 at 5 per cent

: 2.80 at 1 per cent



TREATMENTS

Fig. 46. EFFECT OF GRANULAR SOIL INSECTICIDES ON ADULTS OF COSMOPOLITES SORDIDUS.

untreated control (Fig. 46). The number of adults recovered from plants treated with phorate (1.83); carbofuran (2.67); and quinalphos (3.33) were significantly less as compared to that of the plants treated with disulfoton (15.33), there being no significant difference among them. However, disulfoton showed significantly less number of adults as compared to untreated control (20.67) (Table XIV).

## ***DISCUSSION***

## V. DISCUSSION

Since very little information was available on the biology and control of banana rhizome weevil, Cosmopolites sordidus (Germar) under Indian conditions in general and Karnataka in particular, detailed investigations were undertaken during the years 1970-1974. Observations were made on the biology including distribution, seasonal incidence, nature of damage, host range and sources of infestation of the pest under field conditions in banana growing areas of Karnataka. Studies were also carried out on the external morphology, life cycle, varietal reaction to the attack of the weevil and chemical control of banana rhizome weevil.

### External Morphology

The present observations revealed that the egg was pure white, elongate and oval in shape and this is in agreement with the findings of Moznette (1920), Sen and Prasad (1953), Hill (1975) and others. However, it deviates from the observations of Jardine (1924) who stated that the egg was rounded at one end and more or less pointed at

the other and that of Tryon and Benson (1920) according to whom the egg was pale yellow. The developmental changes of the egg observed are in line with that of the observations of Froggatt (1923c). The egg measured 1.80 to 1.98 mm in length which is almost in conformity with the observation of Moznette (1920) and McCarthy (1920) (2 mm), Froggatt (1925) (2.11 mm) and Pinto (1928) (1.69 mm) whereas the observations of Tryon and Benson (1920) indicated the length to be 1.33 mm and the cause for this difference can not be explained. The width of the egg ranged from 0.54 to 0.69 mm and this is almost in agreement with the investigations of Pinto (1928) (0.84 mm) and Tryon and Benson (1920) (0.6 mm).

The morphology of larval instars (1 to 6) has been studied in brief for the first time in addition to the detailed external morphology of the seventh (final) instar. The freshly emerged grub was 2 mm (Gendana, 1920) to 2.1 mm (Pinto, 1928) in length which are in confirmation with the present findings (1.99 mm).

The general description of the final instar grub is almost similar to the description made by the earlier workers. However, the deviations observed during the

present investigations have been discussed.

According to Moznette (1920), there were twelve pairs of setae on the epicranium and during the present studies, fourteen pairs of epicranial setae were noticed which have been named based on the terminology used by Anderson (1947). The additional two pairs of setae include one pair in each of posterior epicranial setae and ventral epicranial setae. A pore laterad to  $des_5$  which has been observed during the present studies has not been mentioned by the previous workers.

Five pairs of frontal setae have been observed which is in agreement with the observation of Zimmerman (1968a), whereas according to Moznette (1920) there were only four pairs of frontal setae. Antenna consisted of one membranous article which bore a conical accessory sensory appendage and several minute setae, which made Moznette (1920) to consider antennae as two-segmented.

The morphology of clypeus is in accordance with that observed by Moznette (1920) except for the presence of a pore in front of each lateral seta.

The description of the labrum is similar to that made by Moznette (1920). Epipharynx has a well sclerotised U-shaped bridge the base of which extends beneath the clypeus. This U-shaped bridge has been referred to as labral rods by Anderson (1948) and Epipharyngeal rods by Cotton (1924). According to Cotton (1924) there were two pairs of thickened setae between the epipharyngeal rods but the present investigations revealed that there were three pairs of broad, lanceolate setae along the inner margin of U-shaped bridge.

The mandibles were stout, more or less triangular with bluntly pointed three apical denticles, but Moznette (1920) and McCarthy (1920) observed bidentate mandibles in the species. In addition there were two punctures on the mandible which have not been noticed by the previous workers.

During the present studies a seta associated with a puncture at the base of the mala was seen whereas the observations of Cotton (1924) revealed that there were one branched and two simple setae at tip of mala. Two punctures at the distal end of the basal palpal segment and a group of sensory pegs at the distal tip of the second palpal

segment were also observed during the present findings. The detailed morphology of the labium has been studied and not much of work on labial morphology was attempted by the earlier workers.

The present investigations on chaetotaxy as observed on one side of the body revealed that there are 18 setae on prothorax out of which nine on pronotum, two on pleural, six on pedal area and one on sternum whereas according to Moznette (1920), there were only ten pairs of setae on prothorax.

According to Moznette (1920), there were only ten setae on mesothorax while the present studies revealed the presence of fourteen setae, one prodorsal seta, three postdorsal setae, one seta on each of alar area, spiracular area, pleural area and sternal area and six on pedal area. The seta on spiracular area was long but Anderson (1948) stated that this seta was short.

A total of seventeen setae were noticed to be present on metathorax; one on prodorsum, three on postdorsum, one each on alar area, pleural area and sternal area, four on spiracular area and six on pedal area, but Moznette (1920) and Anderson (1948) have observed only nine pairs of

setae on metathorax.

According to Moznette (1920) each abdominal segment consisted of seven setae while during the present studies twelve setae, one on prodorsum, three on postdorsum, one on spiracular area and two on each of epipleural and pleural areas, one on pedal area and two on eusternum were observed.

Six setae, one on prodorsum, four on the slope and one seta on eusternum were observed on eighth abdominal segment which deviates from the findings of Moznette (1920) who reported only four setae. The ninth abdominal segment according to Moznette (1920) bore four setae while during the present investigations six setae were observed.

The seventh instar grub measured 11.82 mm in length and 5.84 mm in breadth, but according to Fawcett (1913) and Moznette (1920) the grub measured 20 mm and 13 mm respectively in length and 8.46 mm (Pinto, 1928) and 8.0 mm (Fawcett, 1913) in breadth.

The prepupa measured 11.5 mm in length and 3.85 mm in width and the thoracic segments became distinct with ventrolateral lobes which was not observed by previous workers.

In the pupa were two pairs of setae on head, one long and one short and five pairs of setae on beak out of which two were long and tuberculate and three short and according to Moznette (1920) there was only one pair of long setae on head and five pairs of setae on snout out of which three were long and tuberculate and two were tiny.

Metathorax was with three pairs of setae. Each leg with a lateral seta close to the distal end of femur and wingpads extended upto 5th or 6th abdominal segments, and these have not been observed by any of the earlier workers.

The first six abdominal segments each bore four pairs of setae but Moznette (1920) and McCarthy (1920) have reported only three pairs.

The first six abdominal spiracles were more prominent (Moznette, 1920; McCarthy, 1920) and during the present studies the first five abdominal spiracles were only prominent and the sixth was indistinct.

On an average the pupa measured 11.45 mm and 3.90 mm in length and breadth respectively whereas it was 12.00 mm (Moznette, 1920) and 12.70 mm (Tryon and Benson, 1920; Hill, 1975) in length and 5.80 mm in breadth (Pinto, 1928).

The antenna of the adult has been described in detail which consisted of a longer scape, pedicel forming a pivot between scape and flagellum. The pedicel was more or less equal in length to the first flagellar segment. Segments 2 to 5 were almost equal and shorter than first and the last one being very much enlarged and clubbed. These observations were made in addition to the earlier work. In the present study the club was single segmented with the basal part provided with zigzag striations and a circle of six stout setae and the distal part densely covered with short, fine setae. According to Moquette (1920), the club was two jointed, shining with a few minute hairs and the apical joint spongy. The difference in the appearance of the proximal and the distal parts of the club might have led for the conclusion that the club was two segmented.

The detailed descriptions of the mouthparts of the adult has been made for the first time.

The elytra elongate, ellipsoidal, convex with nine longitudinal striations the more anterior one of which confined to only basal half. Hind wings with light brown veins, costa conspicuous only at base, subcosta started behind costa and terminally fused with radius. Radius ran

upto the apical margin and was not clear behind the fusion with subcosta. The median vein lay behind and it was the longest of all the veins and faint. Cubitus was thick which started behind radius and ended abruptly in the middle. Anal veins were two and faint. These observations are in addition to the observations made in the past.

During the present investigations the snout of the weevil measured 2.84 mm in length while the observations of Pinto (1928) and Fawcett (1913) revealed the beak length to be 3.17 and 4.0 mm respectively. The body length of the weevil was 12.55 mm and breadth was 3.75 mm which are almost in agreement with the observation of earlier workers i.e., 11.0 mm (Froggatt, 1923c) to 14.0 mm (Fawcett, 1913) in length and 4.0 (Moznette, 1920) to 4.23 mm (Pinto, 1928) in width.

### Biology

Distribution : The review of literature revealed that C. sordidus is distributed all over banana growing areas of the world. The present study has revealed the distribution of the pest in all banana growing areas of Karnataka. However, it was previously reported only from two places in Karnataka namely, Srirangapatna and

Hessaraghatta (Usman and Puttarudriah, 1955). Another interesting feature that came to light during the current study was that among the districts, Mysore has been identified to be an endemic area with severe infestation of the pest ranging from 80 to 90 per cent.

Economic importance : Though a great deal of damage to and destruction of abacca and banana is reported from various banana growing parts of the world, there is very little reported from India, excepting the assessment by Roy and Sharma (1952) from Sabour, India on the extent of weevil damage (8 to 10 per cent), no information is available on this aspect from any other state of India, and practically nil from Karnateka.

During the present studies, the severity of the pest has been confirmed in different districts of the State, especially Mysore district, with the infestation varying from 80 to 90 per cent. The banana growers from Nanjangud area (Mysore district) were noticed to have abandoned banana plantings (especially variety Rasabale) due to weevil infestation, and have taken up replanting or growing of other crops.

Life cycle : Few workers have studied the life

cycle of C. sordidus (Moznette, 1920; Cendana, 1922; Froggatt, 1922, 1923, 1924, 1925). Except for a brief report by Roy and Sharma (1952), no detailed investigations have been made on the bionomics of C. sordidus in India and Karnataka as well.

The present detailed studies have brought to light certain facts which were hitherto not clearly understood or known. The eggs were observed to be laid singly in the outer leaf sheaths and rhizomes, which is in agreement with the observations of earlier workers. In addition to the different locations of eggs mentioned by previous workers, the eggs were observed during the present investigation to be laid inside the rhizome and also in the centre of the pseudostem where they were loosely laid without being inserted into the tissue. The adult laid eggs on the rhizome beneath the soil and on pseudostem upto a height of 25 to 30 cm from the surface of the soil, whereas Fawcett (1913), Jepson (1914) and Cendana (1922) stated that there was no specific height from the surface of the soil, where the egg was laid.

The incubation period varied from five to ten days, with an average of 6.87 days which agrees with that reported by de Azevedo (1922), McCarthy (1920), Moznette (1920),

Cendana (1922), Froggatt (1924), Edwards (1925), Urich (1925), Pinto (1928), Harris (1947), Siliezar (1961), Braithwaite (1963) and Schmidt (1965). In contrast, varying incubation periods of 21 to 27 days (Froggatt, 1924), 4 days to 4 weeks (Weddel, 1945), one to three weeks (Simmonds, 1966) and 5 to 15 days (Trezo, 1969) have been observed. This wide range of variation may be due to the great fluctuations in climatic conditions under which the studies have been made by them.

Hatching was observed to be 100 per cent except during the months of October to January when it ranged from 44.30 to 90.0 per cent. The fall in hatching percentage during this period may be due to low temperature. In order to confirm this, a batch of eggs were placed in an incubator at a temperature of 27°C. At this temperature all the eggs were found to hatch. This observation is more or less in line with the observation of Froggatt (1922) who stated that egg development decreased during cold climatic conditions resulting in poor hatching.

The larval development was completed through seven instars with seven moults in both sexes. This observation differs from the findings of Cendana (1922) who reported six instars with six moults and two to four moults reported by

Froggatt (1923, 1924). However, the number of instars mentioned by Froggatt (1923, 1924), being inconsistent may be overlooked.

The larval period from different countries has been reported to be 15 to 165 days and has been found to be influenced by climatic conditions. The present investigation has revealed the larval period varying from 36.6 to 44.6 days, this little variation being influenced by the seasons in which development took place. A longer larval period was observed during November through February (44.6 days), and a shorter one during July through September (36.6 days). The previous workers have not indicated the temperatures under which studies were made. The cause for the extended larval developmental period observed in Bangalore may be due to the influence of the prevailing cold climate.

The present revelation as to the difference in the duration of the larval development in summer (short) and winter (long) definitely points to the high sensitivity of the grub to fluctuations in weather factors. Perhaps this accounts for such wide variations (15 to 165 days) observed in different parts of the world.

In regard to the duration of each instar the first instar has been observed to occupy 3 to 5 days; second instar, 5 to 7 days; third instar, 5 to 7 days; fourth instar, 5 to 7 days; fifth instar, 5 to 8 days; sixth instar, 5 to 7 days and seventh instar, 6 to 8 days. These durations agree with the studies made by Cendana (1922) who reported a period of 5 to 8 days (I instar), 4 to 8 days (II instar), 5 to 8 days (III instar), 6 to 8 days (IV instar), 5 to 10 days (V instar) and 6-8 days (VI instar). The only difference is in regard to the number of instars which is seven as in the present studies and six in the latter.

The fully grown grub stayed quiescent in the pupal cavity which lasted for 1 to 3 days (Pinto, 1928; Froggatt, 1922, 1925; Roy and Sharma, 1952). Similar observation has been made in the present study, wherein period of quiescent lasted for 2 to 3 days. Froggatt (1922, 1925) and Roy and Sharma (1952) have reported that the prepupa exhibited little powers of movement if disturbed. Contrary to this, in the present studies it was noted that the prepupa exhibited linear rotary movements in the pupal cavity even without disturbance. At the end of the prepupal period ecdysis occurred by the rupturing of head capsule and the thoracic

integument along the mid-dorsal line. This has not been reported by earlier workers.

Froggatt (1922, 1925) and Roy and Sharma (1952) observed the formation of the pupal cell underneath the surface of the rhizome and further they stated that the pupal cell was formed as far as two inches from the surface of rhizome in cases of severe infestation. The present observations are more or less in conformity with the earlier reports. Further, the study showed that the pupal cell was not only formed deep in the rhizome, but also in the pseudostem during heavy infestation. No cocoon was formed except that a few fibres were found lining the pupal chamber when it pupated in pseudostem. This is in agreement with the observations made by Froggatt (1922, 1925) and Roy and Sharma (1952) who reported that a few strands of fibres were noticed at the end of the tunnel in the pupal chamber and also when pupation took place in tissues of leaf sheath. The presence of more fibrous material in the cell formed in the leaf sheath may be due to the fact that the grub could not excavate a perfect cell in the leaf sheath, which was possible only in case of rhizome and so in the former it formed a cell with the help of fibres after cutting a rough hole.

The pupal period as revealed in the present investigation occupied an average of 7.15 days. The pupal period was observed to be prolonged during September through March (7.2 to 8.8 days) while it was shortened during other months (6.4 to 6.5 days) with the minimum and maximum periods being 6 and 11 days respectively. The observation is almost in conformity with the reports made by earlier workers barring that of Froggatt (1921, 1923, 1924) and Simmonds (1966) who have reported the pupal period to occupy 4 to 15 days and 21 days respectively. This variation may be attributed to the influence of climatic conditions prevailing in those countries. The rotary movements of the abdomen of the pupa when disturbed has not been reported earlier.

The newly emerged weevil remained in the pupal cell for two to four days, which is comparable to the periods of 6 to 7 (Froggatt, 1921, 1923), 4 to 5 (Edwards, 1925) and 3 to 6 days (Jardine, 1924). The little difference in the period between the present observations and previous findings may be due to different local weather conditions prevalent at the time of observations. Later the adult made a hole on the rhizome and came out. However, Cendana (1922) reported that the adult weevil pushed its way out

of the rhizome. During the present studies it was observed that the grub did not make any emergence hole before pupation, and the adult cut a hole in the pupal cell and bored through the rhizome.

Present studies showed that the weevils, after emergence, fed upon leaf sheath by mining into the leaf sheath, where they fed upon the tissue inbetween the two epidermal layers, besides feeding upon the rhizome also. This observation agrees with that of Froggatt (1921, 1923, 1925). However, Roy and Sharma (1952) claimed that the adult did not cause any damage. According to Hill (1975) its normal food was dead and dying banana plants.

The weevils were found to be active only in the night and during the day they were sluggish and hid themselves beneath the cut length of the pseudostem or rhizome in the studies carried out in the laboratory, and in the field observations majority of them were seen confined inbetween the two epidermal layers of the leaf sheath after mining and at times inbetween the rhizome and soil. Earlier studies of Harris (1917), Megnette (1920), Cendana (1922), and Edwards (1925) confirmed the present findings. Adults were always found in places where the humidity was high and

hence they were invariably wet, thereby confirming an earlier observation by Whalley (1925). A further revelation made out during the present studies was that when weevils were removed from these damp places, a dull black colour and later formation of greyish encrustation developed on the body of the insects. The adults were usually gregarious as was reported by Moznette (1920) also.

In addition to the hiding places discussed above, the weevils were observed to inhabit larval tunnels deep in rhizomes and in the centre of pseudostem upto a height of 60 to 75 cm above the soil surface as well.

The adult was observed to feign death when disturbed, which was also observed by Moznette (1920) and Froggatt (1925). During feigning of death the bases of the antennae were seen to be approximated to the snout along the furrows.

The total life cycle from egg to adult varied from 50 to 70 days with an average of 56.63 days, agreeing with the observations of Cendana (1922) who reported a duration of 52 to 56 days, and Froggatt (1922) who recorded 62 to 63 days in September and 48 to 59 days in October. However, it contravenes the findings of many earlier workers according to whom it was one month (Anonymous, 1917; Watts, 1917;

Harris, 1947) and 31 to 33 days in November and 120 days in June (Froggatt, 1922). But according to Froggatt (1925) and Braithwaite (1963) the pest completed its life cycle with an average of 47 days with a minimum of 29 days in summer and a maximum of 180 days in colder months. Various other workers have reported different periods for completing one generation. It was 25 to 35 days (Urich, 1925), 5 to 6 weeks (Ghesquiere, 1927), 36 to 38 days (Moutia, 1931) and 31 to 33 days in summer and 132 to 134 days in winter (Froggatt, 1924).

The insect was not seen flying at any time, which confirms the findings of Froggatt (1923). However, in one experiment when temperature was maintained at 35°C and humidity at 65 to 70 per cent, the weevils were found opening the wings but never took to flight. This observation differs from that of Watts (1917), Urich (1925), Simmonds (1929, 1932, 1935) and Froggatt (1924) who claimed that the weevils did fly under certain climatic conditions. In any case the flight of the weevil has not been proved experimentally.

Copulation took place between 6.30 to 8 p.m. under laboratory conditions. However, the mating was also observed during day time whenever the weevils were released on

to the fresh food source while changing the food. Copulation took place 10 to 15 days after emergence and lasted for 4 to 5 minutes. Previous workers on this insect did not report on these aspects of copulation.

During copulation, the male weevil rested at an angle of about  $45^{\circ}$  over the female, having a firm hold on the female with the help of meso- and meta- thoracic legs, while the prothoracic legs were used to adjust the body movements during mating. Froggatt (1923) also made a similar observation in regard to the mating posture.

Pre-oviposition period varied from 15 to 28 days with an average of 20.5 days which according to Froggatt (1922, 1923, 1925) ranged from 14 to 99 days. This difference is difficult to explain; however, it may be stated here that the females which came out in the early part of winter and got fertilised might have taken more time for laying the first egg.

Egg laying was observed to be during night in the laboratory, none the less a few eggs were collected during day time also. According to Simmonds (1966) the weevils came out during night to feed and lay eggs.

A fertile female during its life time laid 36 to

53 eggs with an average of 45.9 eggs. However, Simmonds (1966) stated that the total number of eggs laid varied from 10 to 75 and in exceptional cases 100 and according to Fryon and Benson (1920) it was 14 eggs or less and Hill (1975) reported the fecundity to be 10 to 50 eggs or more.

Another interesting observation made was the oviposition period of the adult weevil which varied from 313 to 556 days with an average of 471.7 days. The peak of egg laying period was noticed at the age of 7 months. This is almost similar to the observations made by Froggatt (1922, 1923, 1924) who stated that oviposition was throughout the life of female weevil influenced only by seasonal climatic variations in that the egg laying decreased with the advent of cold weather and also possibly the age of the insect. Oviposition period occupied 16 to 21 months whereas the post-oviposition period was very short which lasted for 14 to 57 days, the average being 35.4 days.

With regard to the longevity of the adult, it was more (546 to 582 days with an average of 564.5 days) in the case of adults obtained in the laboratory which were reared from the field collected grubs. On the contrary, the laboratory reared individuals survived for 369 to 443 days. These findings compare fairly well with the

observations of Harris (1947), Schmidt (1965) and Simmonds (1966) reporting two years to little over two years in the case of field collected material; Cendana (1922) reporting 103 days in captivity, Froggatt (1923) recording 471 to 488 days; Froggatt (1924) reporting 16 to 21 months; Jepson (1914) who reported 16 weeks and Jardine (1924) recording 5 to 8 months. From the above observation it was established that adults reared from the field collected grubs had a longer life over the adults obtained from grubs reared completely under laboratory conditions.

Moisture appears to be the dominant factor determining longevity of the adults. The adults were noticed to survive for a long period even without food provided they were maintained under damp conditions. They lived for 98 to 128 days without food and 348 to 421 days with food in wet soil. In contrast to this, they survived only for 8 to 14 days without food and 12 to 18 days with food in dry soil. This is in close agreement with the observations of Froggatt (1923, 1924) according to whom the adults died within 5 to 6 days in dry soil without food, and lived for more than 100 days when the soil was damp in cooler months or in general 70 to 121 days and died if exposed to sun in few seconds.

The sex ratio was also determined both in laboratory reared individuals and also in field collected individuals. In both the cases the proportion of males was more compared to females (1:1.2- laboratory reared; 1:1.4-field collected). This is in accordance with the observations of Simmonds (1933) who found 54 males to 46 females.

The weevil has been reported to breed throughout the year in Trinidad (Urich, 1925), but with decreased rate in the hot summer and cold of winter as compared to spring and autumn in Queensland (Froggatt, 1923). Urich's (1925) observations were confirmed during the present investigations in that the weevils bred throughout the year, but the incidence of adult weevils was minimum from November to January (64 to 89), while the highest incidence was noticed in the month of July (221). This observation differs from the observations reported by Freeman (1919) from Trinidad who collected 644 adults during December, 511 adults during January, 270 adults during February and 341 adults during March; Froggatt (1925) who collected 30,000 beetles between February and July, 1222 beetles during August and 1472 during September, and Gomez Clemente (1947) who reported from Africa that the number of weevils collected reached maximum during January to March and October

to December. However, the present observations are in accordance with those of Wallace (1938) who reported from Australia that the beetles were attracted to baits freely during the months of September to April and avoided baits in severe winter which confirm the results obtained during the present investigations in that more weevils were attracted to baits during summer months and less during winter months.

According to the present study the weevil could complete a maximum of five generations in a year. But under field conditions overlapping of generations occurred because of the prolonged oviposition period of 313 to 556 days. This is in agreement with the observations made by Cendana (1922) who also indicated more than five generations in a year in Philippines. However, Shiraki and Sonan (1937) recorded that the weevil had four generations in one year in Taihoku, Japan.

C. sordidus undoubtedly spread from one country to other and from one plantation to the other plantation by the transportation of infested suckers and root stocks used for propagation purposes (Cendana, 1922; Froggatt, 1924; Roy and Sharma, 1952; Schmidt, 1965) and the spread

of the beetle was also observed by way of crawling from infested area of a plantation to the other healthy areas of the same (Cendana, 1922, Froggatt, 1924; Roy and Sharma, 1952; Braithwaite, 1963). The present investigation confirmed the above observations. In the field, in the early stages of infestation, it was observed to be localised and only after exhausting the source of food the weevils migrated to the nearest stool by walking. In addition to this, Simmonds (1929, 1932, 1935), Froggatt (1925), Roy and Sharma (1952) were of the view that the mode of infestation was also by flying. However, this could not be established during the present studies since the adults were not observed to take to flight. Froggatt (1925) and Roy and Sharma (1952) were of the opinion that the weevil got distributed by washing down due to rain water or flood water in gullies and steep slopes. This may be possible in areas where bananas are grown on hills and in valleys (like Coorg and Chikmagalur districts of Karnataka).

The adults caused damage by scraping the tissue inbetween the two layers of epidermis of the outer leaf-sheaths, which gradually decayed, and the portion above the fed area dried gradually. These observations on the symptoms caused by adult feeding are in conformity with

those of Froggatt (1921, 1923, 1925). However, Roy and Sharma (1952) mentioned that the adults did not feed.

The grubs have been noted to follow more or less a particular course in the rhizome during their development. The grubs after hatching bored through the leaf sheath in a linear way, entered into the rhizomes and fed on the internal tissue. At first the grub tunnelled downwards through the peripheral region of the rhizome towards the root base causing severe injury to the roots at the point of origin. After sometime the grub started tunnelling back towards the growing point. Later, towards the end of larval life it again tunnelled towards the peripheral region of the rhizome. As the grub bored, it packed the tunnels with frass. The size of the tunnel increased with the size of the grub. When a large number of grubs were present, the tissue got reduced into a felty mass. These observations are in conformity with the studies of Fawcett (1913), Fletcher (1914), Jepson (1914), Froggatt (1919), Moznette (1920), Cendana (1922), Pinto (1928), Harris (1947), Braithwaite (1963), and Gaud. et al. (1975).

When most of the rhizomes were riddled, the tunnelling of pseudostem was seen upto a height of 75 to 90 cm from the ground surface, which confirms the observations of

McCarthy (1920), Froggatt (1925), Roy and Sharma (1952), Braithwaite (1963) and Feakin (1971) who stated that the tunnelling extended from one to four feet from the soil surface.

The symptoms accompanying the attack of the grubs when the infestation extended to pseudostem was the typical marginal drying of the outer leaves which gradually spread to the inner leaves, by which time the outer leaves completely dried up. In severe cases, where the growing point was affected, dead-heart was observed on the plants. Plants in which growing point was unaffected, produced a weaker bunch with less number of hands and small fingers. Further, in the case of severe riddling of rhizome the pseudostem when pushed gave way at the point of attachment with the rhizome. These observations are almost similar to the reports of McCarthy (1920), Cendana (1922), Froggatt (1922), Harris (1947), Sen and Prasad (1953), Braithwaite (1963) and Gaud. et al. (1975).

Another interesting revelation brought out during the present studies was that even a single grub could cause dead-heart in banana plants. When the grub attacked the growing point, it caused a dead-heart with all the outer leaves apparently normal. This observation is in agreement

with the report of Froggatt (1923) who was of the view that even a single larva might be sufficient to kill the plant. However, it contradicts the findings of d'Emmerez and Gebert (1921) who emphasised that the attack by large number of grubs was required to cause the death of the plant.

Froggatt (1925) reported that C. sordidus attacked potato tubers and arrow root (Canna edulis) and Wolcott (1922) on Yam and guinea grass. During the present studies the underground parts of Amrophophallus campanulatus, Ipomoea batatas, Canna orientalis, Manihot esculenta and Solanum tuberosum when provided to adult weevils and grubs were not accepted as food. However, all the varieties of banana were found to serve as hosts for this insect as they were found damaged.

#### Varietal response of banana to the development of C. sordidus

Considerable amount of work has been carried out on the varietal response as revealed by studies of Hutson (1918), d'Emmerez and Gebert (1921), Froggatt (1921, 1925), Cendana (1922), Gowdey (1923), Ghesquiere (1927), Wolcott (1934), Millard (1952), Roy and Sharma (1952), Sen and Prasad (1953), Hord and Flippin (1956), Elias (1960) and

Simmonds (1966).

In order to know the response of local cultivars, fifteen varieties of banana which incidentally included some of the varieties already tested, namely, Cavendish, plantain (Maduranga), Lacatan, Musa acuminata, M. balbisiana were tested for their reaction to the attack of the weevil. The parameter used to determine the varietal reaction was relative number of immature stages present after an interval of 60 days after infesting the plants with a constant number of adults. The variety Lacatan was less susceptible (2.67 immature stages) compared to Maduranga which was highly susceptible by recording 32.00 individuals. There was significant difference among the varieties included under the study. In addition to Maduranga, Peykunnan (22.67) also harboured significantly higher number of immature stages as compared to remaining varieties. Next in order were Budubale (16.33) and Nallabontha (13.33) which also supported significantly higher number of immature stages with no significant difference existing between them. Varieties Lacatan, Cavendish (D), M. balbisiana, Cavendish (R), Poovan, and Virupakshi harboured the lowest number of immature stages ranging from 2.67 to 4.67 and significantly differed from M. acuminata, Nendran, Sirumali and Neyypoovan.

Neither the former group of varieties nor the latter group showed any significant difference among themselves.

Rasabale was on par with all the varieties except with Nallabontha, Budubale, Peykunnan and Maduranga.

Contrary to the observations of Froggatt (1921, 1925) and Hord and Flippin (1956), the present studies revealed the varieties Cavendish and M. acuminata to be less susceptible. The observation that Maduranga was highly susceptible conforms to the findings of Froggatt (1921, 1925). The observations made by Cendana (1922) and Hord and Flippin (1956) that the varieties Lacatan and M. balbisiana were less susceptible are in line with the present findings.

#### Chemical control of C. sordidus with granular soil insecticides

Extensive information is available on the chemical control of banana rhizome weevil using insecticides other than granular formulations. Bullock and Evers (1962) were the first to test the granular formulations like aldrin (10 per cent), dieldrin (10 per cent) and heptachlor (10 per cent) at 2 lb a.i. per acre and reported diel-drin to be

superior to others. Wolfenberger (1965) brought to light the superiority of granular formulations viz., aldrin, dieldrin and heptachlor over insecticidal emulsions of the same in the control of banana rhizome weevil. Accordingly, in the present investigation four granular insecticides of which three were systemics, namely, phorate 10G, carbofuran 3G, disulfoton 5G and the other nonsystemic, quinalphos 5G, were tested at 1 kg a.i. per acre applied one month after planting for their efficacy in the control of the rhizome weevil. All the four insecticides have provided effective control showing significant difference over the check. Among the insecticides phorate 10G (10 gm/stool) was found to be most effective (3.33 immature stages/stool) followed closely by carbofuran 3G (33 gm/stool) (4.33 immature stages/stool) and then by disulfoton 5G (20 gm/stool) (7.83 immature stages/stool) and quinalphos 5G (20 gm/stool) (11.33 immature stages/stool). The effectiveness of carbofuran 10G (10gm/plant) and disulfoton 10G (14 gm/plant) have been studied along with the other insecticides by Gaud et al. (1975) who reported the superiority of carbofuran over the other insecticides, which is confirmed in the present studies also but being superseded by phorate. Incidentally, phorate and quinalphos have been tested for the first time in the present investigations

against banana rhizome weevil.

Granular insecticides with systemic action (phorate, carbofuran and disulfoton) have proved significantly better than the granular insecticide with contact action (quinalphos) in killing the immature stages. On the contrary, quinalphos has joined the ranks of phorate and carbofuran (without significant differences among them) in providing effective control of the adult weevils, and all these three showed significant difference over disulfoton which inturn proved better than control.

Based on the above results, it is concluded that with their consistant performance relating to control against both immature stages and adult weevils, phorate and carbofuran (in that order) may be used for checking the weevil infestation.

# ***SUMMARY***

## VI. SUMMARY

The present investigations on the banana rhizome weevil, Cosmopolites sordidus (Germar) include a study on the external morphology of different life stages; biology including distribution, economic importance and life cycle; response of certain varieties of banana to the attack of rhizome weevil, and chemical control of the weevil using granular soil insecticides.

1. The external morphology of egg, larval instars, prepupa, pupa and adult have been briefly described giving measurements of the head capsule and body. A detailed description including the chaetotaxy of the seventh (last) instar larva is provided.
2. The biology of the banana rhizome weevil was studied in detail. The incidence of the weevil was observed in all the districts of Karnataka except in Bidar, Bijapur, Gulbarga and Raichur which have not been surveyed. The pest was serious in Mysore district in that 80 to 90 per cent of banana plants were infested in Devarasanahalli and Manjangud area.

The study of the life cycle of the insect through six generations under laboratory conditions has revealed that the eggs were laid inserted singly in various locations in the leaf sheath and rhizome. Seven larval instars were noticed. Pupation was usually in the peripheral region of the rhizome close to the surface in a pupal chamber. The incubation, larval, prepupal and pupal periods were observed to be 5 to 10 days (average, 6.87 days), 36 to 46 days (average, 39.9 days), 2 to 3 days and 6 to 10 days (average, 7.15 days) respectively. The total life cycle of the weevil from egg to adult ranged from 50 to 70 days (average, 56.63 days).

The adults lived for 424.5 days. Moisture appeared to play a critical role in determining the longevity, those maintained in moist soil even without food living for 111.96 days, while those kept in dry soil living only for 9.96 days.

A female laid 36 to 53 eggs during a period of 424.5 days. The pre-oviposition, oviposition and post-oviposition periods were noted to be 20.5, 471.7 and 35.4 days respectively. The weevil completed five generations during the year under laboratory conditions. The sex ratio of the weevils, i.e., female to male was 1:1.4 in the field

collected adults and 1:1.2 in the laboratory reared individuals.

The incidence of the weevil was minimum during November to January and increased gradually from January to June and with a steep fall from July to November.

The external symptom of the damage caused by the grubs was typical marginal drying of outer leaves which extended to the inner leaves also gradually, by which time the outer leaves dried up completely. In severe cases of damage where the growing point has been affected, dead heart was noticed.

The weevil was observed to feed and breed only on Musa spp. Both the grubs and adults did not survive on the underground parts of elephant foot, sweet potato, canna, tapioca and potato when provided in the laboratory.

3. Fifteen varieties of banana tested to study their response to the development of C. sordidus revealed that the variety Lacatan was least susceptible while Maduranga was the most susceptible to the attack of the weevil. Variety Peykunnan was next to Maduranga, followed by Budubale, Nallabontha, Neypoovan, Nendran, Sirumali, M. acuminata, Rasabale, Virupakshi, Poovan, Cavendish (R), Cavendish (D)

and M. balbisiana in the increasing order of relative tolerance.

4. Studies conducted on the chemical control of C. sordidus using four granular soil insecticides, namely, carbofuran, phorate, disulfoton and quinalphos each at 1 gm. a.i. per plant indicated that phorate was superior followed by carbofuran, disulfoton and quinalphos in controlling immature stages. Phorate maintained its effectiveness even in the control of adults followed by carbofuran, quinalphos and disulfoton.

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