BIOLOGY, BIONOMICS AND CONTROL OF COCONUT COCKCHAFER *LEUCOPHOLIS CONEOPHORA* BURM.

By
V. A. ABRAHAM

THESIS
SUBMITTED IN
PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

Division of Agricultural Entomology
COLLEGE OF AGRICULTURE
Vellayani - Trivandrum

1983

D E C L A R A T I O N

I hereby declare that this thesis entitled "Biology, Bionomics and Control of Coconut Cockchafer Leucopholis coneophora Burm." is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar titles of any other University or Society.

Place: Vellayani
Date: 8 September, 1983

(V. A. ABRAHAM)

C E R T I F I C A T E

Certified that this thesis entitled "Biology, Bionomics and Control of Coconut Cockchafer Leucopholis concophora Burm." is a record of research work done independently by Shri. V.A. Abraham under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

(Dr. M. MOHAN DAS)
Chairman
Advisory Committee
Professor of Agricultural Entomology
College of Agriculture
Vellayani

Vellayani
8 September 1983

Approved by

Chairman

Dr. N. Mohan Das

Members

Dr. M.R. Gopalakrishnan Nair

Dr. Chandy Kurian

Dr. R.S. Aiyer 1.12.83

Dr. A. Visalakshi 1.12.83

ACKNOWLEDGEMENT

I wish to record my deep sense of gratitude to Dr. N. Mohan Das, Professor, Agricultural Entomology, College of Agriculture, Vellayani, Trivandrum, for the valuable guidance and constant encouragement during the course of the study and in the preparation of the thesis.

I am indebted to Dr. Chandy Kurian, Head, Division of Entomology, Central Plantation Crops Research Institute, Regional Station, Kayangulam, who is also a member of the Advisory Committee, for the valuable suggestions and encouragement during different phases of the present investigation.

I am equally indebted to Dr. M.R.G.K. Nair, Retd. Professor and Emeritus Scientist (ICAR) whose suggestions and help were very valuable for the completion of the work. I also express my sincere thanks to Dr. R.S. Aiyer, Professor, Agricultural Chemistry and Dr.(Mrs.) A. Visalakshi, Associate Professor, Agricultural Entomology, College of Agriculture, Vellayani, members of the Advisory Committee, for their valuable suggestions at every stage of the investigation.

I sincerely acknowledge the valuable help received from SarvaShri Jose Abraham and P.T.N. Nambiar, Statisticians, CPCRI, in the statistical analysis of the data.

My sincere thanks are due to Dr. M.P. Govindankutty, Scientist-S2, and Shri. James Rosario, Artist Photographer, for the photography and Shri. P.V. Kappachan, Assistant, CPCRI, Regional Station, Kayangulam, for typing the thesis.

Help received from S/e. G. Karunakaran Pillai, M.M. Abraham and Smt. C. Yesodhara Ammal, Jr. Tech. Assts., S/s. S. Krishna Pillai and K. Vasu, Supporting Staff, CPCRI, Regional Station, Kayangulam, is sincerely acknowledged.

I am grateful to Dr. N.M. Nayar, former Director and Dr. K.V. Ahamed Bavappa, present Director, Central Plantation Crops Research Institute, Kasaragod, and Dr. N.P. Jayasankar, Joint Director, CPCRI, Regional Station, Kayangulam, for assigning the Institute Project on white grubs to me, for providing necessary laboratory facilities in the Entomology Division and constant help and encouragement given for completion of the work.

The help received from the Indian Council of Agricultural Research by granting me study leave is also gratefully acknowledged.

V. A. ABRAHAM

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

I N T R O D U C T I O N

The coconut palm, Cocos nucifera Linn., rightly eulogised as "Kalpavriksha", every part of which is put to one use or other, grows abundantly in the south-western strip of India. In Kerala, coconut is the major crop and the size of holdings ranges from a single palm to about one thousand palms, the upper limit being regulated by a ceiling on the land holdings in the State. The importance of coconut in the socio-economic status of Keralites needs no emphasis and it occupies a predominant role in all the culinary preparations, religious rites and commercial and industrial enterprises. The crop offers a great deal of employment opportunities and economic stability to the people. As estimated a total of 7,00,000 ha of land is under coconut cultivation in the State. Coconut is gaining importance in other States like Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Maharashtra, Orissa, West Bengal, Assam, Andaman and Nicobar and Lakshadweep also. The estimated annual yield of about 600 crores of nuts falls short of the country's industrial and dietary requirements by nearly thirty per cent.

Coconut palms are affected by a few diseases and four major insect pests. Among the insect pests, the cockchafer Leucopholis coneophora Burm. prevails as a serious

one in Kerala and in some parts of Karnataka. It assumes importance as its grubs feed on the tender roots of the palm and is, therefore, responsible for damaging the vital parts and causing significant reduction in yield. It is treated on par with three other major pests viz. the rhinoceros beetle, Oryctes rhinoceros L. damaging the crown and spathes, the leaf eating caterpillar Opisina arenosella Wlk. (=Nephantis serinopa Meyr.) gnawing the chlorophyll content of the foliage and the red palm weevil, Rhynchophorus ferrugineus Fabr., the grubs of which feed through the stem into the cabbage, the growing point eventually bringing about the mortality of the palms.

Importance of cockchafers in the production of agricultural crops in India has been recognised since 1970s. Taking into account the severe damage to various crops and the wide distribution in the country white grubs have been declared as national pests (Parasnath and Janardan Singh, 1981). Crop losses to the tune of 30 to 80 per cent were noticed due to the pest in the endemic pockets (Veeresh, 1981). Realising the importance of the white grub problem in the country the ICAR has implemented an All India Co-ordinated Research Project on white grubs with effect from April 1, 1980 operating at six centres. Studies on L. coneophora have not been

included in this project.

Adequate information on the biology and bionomics of L. coneophora is not on record and effective and economic methods of control are not established conclusively. Biology, bionomics and control of the pest have been dealt by Nirula et al. (1952), Nirula (1958) and Veeresh et al. (1982). These publications give only scanty information on the life history, nature and extent of damage, distribution and seasonal occurrence of different life stages and control of the pest. In this context detailed studies on L. coneophora covering the following aspects were taken up:-

1. Life history of the pest in laboratory and in potted plants in field,
2. effect of different host plants viz. cassava, cacao, and wild sunn-hemp, on the development of the insect,
3. symptoms of attack on the above crops and coconut,
4. distribution of the pest with reference to different seasons of the year and at different depths of the soil,
5. relative efficacy of insecticides to the second and third instar grubs assessed with precise bioassay techniques,
6. evaluation of effective pesticides in the field,
7. fixing an effective and economic schedule of insecticidal

application for the control of the pest,

8. assessment of the persistence of BHC and heptachlor in the loamy sand soil of Kerala and
9. vertical movement of the insecticides in soil assessed through bioassay and chemical assay techniques.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Information available on the systematic position and biology of Leucopholis coneophora Burmeister and on the ecology, behaviour and control of the root grubs have been briefly reviewed here.

1.1 Systematic position

Latreille (1802) raised the family scarabaeidae, under this MacLeay (1819) introduced the sub-family melolonthinae. The genus Leucopholis was erected under the sub-family melolonthinae by Dejean (1833). Blanchard (1845) made improvements on Dejean's key to the above genera in the sub-family melolonthinae. Veeresh (1977) evolved a key for the identification of the adults of different genera of melolonthids in Karnataka. Patil (1978) found that the grubs of Leucopholis could be distinguished from those of Holotrichia based on differences in proplegmatia and setal characters. Veeresh (1981) furnished a key for the identification of the South Indian genera of root grubs and these included Leucopholis also.

Burmeister (1855) erected the species coneophora under the genus Leucopholis. Brenske (1892) furnished details of 29 species of Leucopholis and L. coneophora Burm. was one among them. Brenske (1894) studied the morphology

of Leucopholis spp. and pointed out the importance of wing characters in identifying the species coneophora. Veeresh et al. (1982) made a comparative study of the diagnostic characters of the grubs of three species of Leucopholis viz. Leucopholis coneophora Burm., Leucopholis lepidophora Blanchard and Leucopholis burmeisteri Brenske.

1.2 Biology of Leucopholis coneophora Burm.

Nirula et al. (1952) briefly described the adult, grub and pupal stages of L. coneophora collected from field.

Nirula and Menon (1957) made further studies on the biology of the pest and they observed that the insect had an annual life cycle and the adults emerged en masse within a couple of weeks commencing from the onset of rain and they remained active for about eight weeks. The eggs laid in soil in June/July hatched in 20 days. They also observed that grubs fed till April or early May and then pupated.

Seshadri (1957) had included the drawings of different life stages of L. coneophora in his paper on soil pests of Kerala.

Nirula (1958) gave further details on the biology of the pest. He described the life stages of the pest

briefly. He also observed that the eggs which were creamy white, translucent and smooth when freshly laid absorbed moisture and increased in size during embryonic development. It became dirty white at hatching. Freshly emerged grubs were white with light brown head. He observed that early instar grub fed mostly on organic matter and roots of grasses. Pupal period was observed as 20 days. The adult longevity was recorded as one month and males were seen dying earlier than females. Adults laid eggs for 15 to 35 days after emergence. Oviposition commenced 4 to 7 days after mating. Adults lived for one to four days after completion of egg laying.

Sekhar (1958) furnished a detailed morphological description of the adult of L. coneophora. He reared the grubs collected from field in the laboratory and found that the duration of first instar grub was shorter than that of the final instar. Final instar grubs entered into prepupal stage within 20 to 33 days from the date of collection from the field. They constructed cells in soil for prepupation from 9-12 days. Pupal duration was observed to range from 26 to 33 days in the laboratory and 28 days in field. The final instar grubs were observed to harbour a large number of eggs and this was attributed as a reason for

the commencement of oviposition immediately after the emergence of the adult. Unmated females laid undersized eggs which did not hatch. The mated females laid 20 to 28 eggs. Adults lived for 19 to 36 days.

1.3 Adult emergence

Adults of L. coneophora emerged from soil during April and remained active up to August with en masse emergence in May-June. Stray beetles were seen in March also (Nirula, 1958).

Other root grubs viz. Holotrichia consanguinea Blanchard in Bihar (Kalra and Kulshreshtha, 1961), Holotrichia insularis Brenske in Rajasthan (Srivastava and Khan, 1963), Holotrichia serrata Fabr. in Bihar (Majumdar and Teotia, 1965), Holotrichia nilgiria Arrow in Mysore (Venkitaramaiah, 1969), H. consanguinea in Rajasthan (Kushwaha and Noor, 1976a), H. serrata in Karnataka (Veeresh, 1981) and in Maharashtra (Raodeo and Deshpande, 1981) and cookchafer beetles of arecanut gardens (Daniel and Kumar, 1976) were also reported to emerge between April and August.

1.4 Factors governing adult emergence

The premonsoon showers were reported to initiate adult emergence of Leucopholis irrorata Chevr. (Lopez, 1931 a), L. coneophora (Nirula, 1958) and H. serrata (Veeresh, 1977).

The amount of rain received was also attributed as a factor influencing the emergence. A total rainfall of 5 to 10 mm was reported as a pre-requisite for the emergence of H. serrata (Veeresh, 1977). Yadava (1981) found that H. consanguinea emerged with 28 mm rain in Rajasthan, while the same species in Maharashtra required 33 mm rain for emergence (Patil and Hasabe, 1981). But Veeresh et al. (1982) observed that Leucopholis emerges only after a couple of rains in May-June since the pupation of this species occurs in deeper layers of 60-70 cm and substantial precipitation was necessary to reach the depth and trigger beetle emergence.

A minimum of 50 per cent atmospheric humidity was found necessary for the emergence of H. serrata (Veeresh, 1977).

Couturier and Robert (1956) reported that low ground temperature was congenial for the emergence of Melolontha hippocastani F.

The peak emergence of the beetles of L. coneophora was reported to coincide with the monsoon showers in Kerala (Nirula, 1958). Same condition was reported for L. irrorata in Philippines (Otanes, 1927), H. consanguinea in Bihar (Kalra and Kulshreshtha, 1961), in Gujarat (Desai and Patel, 1965) and in Rajasthan (Rai et al.,1969) and H. nilgiria in Mysore (Venkitaramaiah and Shamanna, 1973).

The daily flight activity of chafer beetles after emergence was also reported to be influenced by rainfall. Prevalence of rain during the emergence time was reported to hinder the flight activity of H. serrata (Veeresh, 1973a). Zivanovic (1976) found that frequent and heavy rainfall along with low temperature hindered the activity of beetles of Melolontha melolontha (L). H. consanguinea also did not come out on days with rains in evenings (Yadava, 1981). He also found that atmospheric humidity influenced the daily activity of H. consanguinea more than the rain. Even if rain was not received for few days after the commencement of emergence high humidity in the atmosphere maintained the flight activity of the beetles.

Hurpin (1956 a) found that higher temperature combined with sunshine stimulated the evening flight of M. melolontha. Tashiro et al. (1969) reported that Amphimallon majalis (Razoumowsky) was not observed at temperatures below 52°F. Fleming (1972) reported that beetles of Popillia japonica Newman were active on days when temperature reached 21°C. But Yadava (1981) observed that temperature was not a deciding factor on the daily emergence of H. consanguinea.

Flight activity of chafer beetles was correlated with light intensity also. Couturier (1967) found that flight of M. hippocastani was found not only by reduction in intensity of light but also by an increase in the degree of polarisation in evening hours. He observed that violet and near violet light (372-426 mμ) induced the flight of beetles. At sun set and sun rise lights of other wave lengths failed to mask the violet light and that provided the stimulus for emergence. Tashiro et al. (1969) reported the emergence of A. majalis at 130 ft-c and flight to trees at a light intensity of 30 ft-c. Gruner (1974 and 1975a) reported that the flight of Phyllophaga plaei Blanch. was triggered off by a light intensity of 0.1 lux and manipulation of photo-period caused advancement of the evening flight. Yadava (1981) and Patil and Hasabe (1981) also observed that the emergence of H. consanguinea was related to specific light intensity.

1.5 Mating

Mating behaviour of L. coneophora was described briefly by Nirula (1958). The beetles in copulation flew about or moved on the ground or were seen resting on the leaf stalk of plants around the site of emergence. Mating started soon after the emergence of females. The male climbed on the back of the female

and after a short interval the male descended and turned towards the opposite direction of the female but the union did not break. The position of male and female beetles in opposite directions in the mating process was noted in H. serrata (Veeresh, 1977) and H. consanguinea (Patil and Hasabe, 1981) also.

Duration of mating varied in different species. Mating of H. insularis lasted for 15 minutes (Srivastava and Khan, 1963), that of H. serrata for 4-5 minutes (Veeresh, 1977) and that of H. consanguinea for 7-16 minutes (Yadava, 1981).

1.6 Adult feeding

Nirula (1958) reported that the adults of L. coneophora did not appear to feed. Sekhar (1958) dissected the adults collected from field and he could not find any food material in the gut. Cochliotis melolonthoides (Gerst.), (Jepson, 1957) and Anomala velula (Ritcher, 1958) were also reported to abstain from feeding in the adult phase. Adults of A. majalis were observed to have slight feeding only. (Tashiro et al., 1969). Several other species of root grubs are known to be defoliators (Ritcher, 1958).

1.7 Nature of damage caused by root grubs on different crops

1.7.1 Cocoonut.

The first record of L. coneophora as a pest of cocoonut palm was made by Nirula et al. (1952). The roots of infested palms were seen severed off near the boles. Leaves of attacked palms turned yellow and the formation of nuts was reduced. Heavy attack caused immature nut-fall and delayed flowering in older palms and stunting in young palms. Abraham and Kurian (1970) observed that the grubs fed on apical tender region of the roots which affected the process of absorption of nutrients and consequently caused the yellowing of leaves and nut shedding. Veeresh (1976) reported H. serrata as a pest of coconut palm in the plains of Karnataka.

1.7.2 Arecanut.

Leucopholis lepidophora was found associated with roots of arecanut palm in Karnataka (Puttarudraiah and Channabasavanna, 1957). Rao et al. (1961) reported that arecanut seedlings were attacked by Lepidiota sp. (a close relative of Leucopholis) in Karnataka and the attack caused the drooping and drying of leaves. Affected seedlings came off easily since the entire root system was eaten away just below the ground level.

Sometimes the grubs even bored into the bole. Grown up palms attacked by the grubs showed a sickly pale yellowing of leaves, poor production of inflorescence and fall of immature nuts and caused heavy loss in yield. Rajamani and Nambiar (1970) observed that the grubs first attacked tender roots and then the older ones. Stem of the attacked palms tapered and became unsteady and they got easily blown down by wind. Kumar (1974) reported that the palms attacked by L. burmeisteri died fast. Nair and Daniel (1982) observed that the young palms attacked by L. burmeisteri died fast while the older palms continued to survive for a longer period, though they were unproductive. Veeresh et al. (1982) observed that the attack of root grubs on arecanut in Karnataka was severe and the affected trees fell easily in wind or even with little jerk. They further noted that the attacked palms became vulnerable to diseases also.

1.7.3 Cassava.

Leefmans (1915) reported serious damage caused by root grub Leucopholis rorida F. to cassava in Java for the first time. The affected plants drooped owing to serious damage to the roots. The young plants died

when the grubs damaged the roots and stem. Nirula (1958) noted that the grubs of L. coneophora burrowed into the fleshy tubers and they remained in the same tuber till the entire food material was eaten up. Phyllophaga sp. and L. rorida were also reported as serious pests of cassava in Columbia (Bellotti and Schoonhoven, 1979).

1.7.4 Other root/stem tubers.

Nirula (1958) reported that L. coneophora caused damage to roots of yam, colocasia, sweet potato and other underground tubers in Kerala. Lal and Pillai (1977) found that L. coneophora attacked Dioscorea alata and Dioscorea esculenta also. Veeresh and Viswanath (1983) found that potato and other tuber crops in Karnataka suffered total loss due to white grub incidence when the crop was subjected to attack at the time of tuber formation and the attack at grown up stages of the crop reduced the market value of the tubers though there was no reduction in yield.

1.7.5 Rubber.

Rubber nursery was seen attacked by L. rorida in Java (DeFluiter, 1941). The tap roots of affected plants were eaten near to soil and plants were getting killed (Edgar, 1958). Rao (1965) found that the root grubs fed the rootlets of plants in nursery and

progressively consumed the lateral roots, eventually reached the tap root which also got debarked. As a result of this damage the seedlings turned yellow, shoots got dried up and ultimately they fell in wind. A single grub could destroy the entire root system of a small seedling and cause its death (Anon. 1968). Outbreak of L. rorida and L. tristis Br. caused heavy damage to immature rubber plants in Malaysia (Anon. 1976).

Leucopholis pinguis Burm. also was reported as injurious to rubber plants in nursery (Beeson, 1921). Abraham and Rajendran (1978) reported a severe incidence of H. serrata on rubber seedlings in nurseries in Kerala. The attacked plants did not show any external symptom of damage though the tap roots were seen eaten up since such plants had produced many lateral roots. But when these plants were transplanted in the main field, they got uprooted in wind.

1.7.6 Sugarcane.

Otanes (1925) noted that sugarcane in Philippines was severely attacked by L. irrorata. Roots and stem were seen eaten up and as a result the plants wilted extensively. Uichanco (1928) reported L. irrorata as the most injurious root grub of sugarcane in Philippines.

Prasad and Thakur (1959) recorded heavy incidence of the grubs of H. consanguinea on sugarcane in Bihar. Kalra and Kulshreshtha (1961) reported from Bihar that the grubs of H. consanguinea fed on the rootlets and root hairs of sugarcane in such severity that the entire root system was paralysed. Grubs were found associated with main roots. They fed by cutting roots at their bases. Larvae injured the main stalk also but they were never found within the stalk. Lightly infested clumps in which roots were not completely cut recovered while heavily damaged clumps dried out. Martorell and Goud (1965) observed that white grubs caused a reduction of 15 to 20 tonnes of cane per acre when the infestation ranged from 10,000 to 20,000 grubs per acre. Gruner (1975b) reported that three or more grubs of Phyllophaga patrueloides Paulian per sugarcane clump significantly reduced the number of stems per clump. A population showing more than ten larvae per clump reduced the height of cane by about 10 per cent. Sithanantham (1978) found that H. serrata damaged the underground portion of sugarcane and caused the death of plants. Mammon (1981) reported drying of 1-3 month-old sugarcane seedlings due to the attack of grubs of Schizonycha ruficollis F. in Pandalam, Kerala. The root system was eaten away and initial yellowing of

leaves, drooping and drying of the inner spindle and consequent deterioration of mature stalk were noticed.

1.7.7 Groundnut.

Rai et al. (1969) described the nature and feeding of H. consanguinea on groundnut and symptoms caused by the pest. The grubs ate away nodules of the plants and the fine rootlets and also girdled the main root. Varieties having a tap root system were highly susceptible to the attack. Affected plants became pale with a wilted appearance and finally dried out.

1.7.8 Sunflower.

Veeresh (1977) observed that sunflower was susceptible to H. serrata though the plants could withstand the attack when enough moisture was available in the soil and the tap root was not damaged. But Sukhija (1978) found that white grub incidence on sunflower in Kashmir caused stunting and drooping of leaves followed by death of the plants.

1.7.9 Cereals.

Teetes (1973) recorded the incidence of Phyllophaga crinita (Burm.) on sorghum and wheat and he noted that significant loss occurred when the grub population was 2/ft^2 or greater. Apostol and Litsinger (1976a) found that L. irrorata on corn

caused the stunting of plants and low yield. Affected plants turned purple before drying.

A single grub per foot of P. japonica reduced the yield of blue grass by 13 to 30 per cent depending on soil moisture. With greater population densities yield reduction was considerably high (Ladd and Buriff, 1979).

1.8 Seasonal distribution of the life stages of root grubs

Nirula and Menon (1957) observed that eggs of L. coneophora were present in June-July only, while Nirula (1958) reported that eggs were seen up to August.

Eggs of H. insularis were also reported to occur in June-July (Srivastava and Khan, 1963) and those of H. serrata from February to July (Majumdar and Teotia, 1965), of H. consanguinea from July (Rai et al., 1969), of H. nilgiria from July (Venkitaramaiah and Shamanna, 1973). But the eggs of H. serrata were reported to occur from April to August in Bangalore (Veeresh, 1973a) and from June to August (Raodeo and Deshpande, 1981) in Maharashtra.

Larvae of L. irrorata were seen from May/June to January/February/March (Lopez, 1931 a). Nirula (1958) observed the first instar grubs of L. coneophora in field in June/July and the third instar grubs up to the

month of May. Desai and Patel (1965) reported that grubs of H. consanguinea prevailed in the field up to November. But Rai et al. (1969) could find them only up to October. Apostol and Litsinger (1976a) found that the first and second instar larval population of L. irrorata peaked in early and late June and third instar grubs in November. Veeresh (1977) reported that the first instar grubs of H. serrata were seen from April to July, second instar from April to September and third instar from May to February.

Pupae of L. irrorata were reported to occur from April to June (Otanes, 1925). But Apostol and Litsinger (1976a) found the pupae of this insect from February to March. In the case of H. serrata pupae were seen from September to March (Veeresh, 1977) and H. consanguinea from September to November (Yadava, 1981).

1.9 Distribution of the life stages of root grubs in different depths of the soil

Vertical distribution of different stages of root grubs in soil was studied by various workers. Nirula (1958) found the eggs of L. coneophora in soil at a depth of 7.5 to 15 cm.

Eggs of L. rorida were seen at 25 to 85 cm depths (Leefmans, 1915), L. irrorata at 20 to 30 cm (Lopez, 1931a)

H. consanguinea at 5 to 10 cm (Kalra and Kulshreshtha, 1961), Holotrichia longipennis (Blanch.) at 2.5 to 5 cm (Haq, 1962), H. insularis at 2.5 to 15 cm (Srivastava and Khan, 1963), H. serrata at 15 to 23 cm (Majumdar and Teotia, 1965), H. nilgiria at 30 to 40 cm (Venkitaramaiah and Shamanna, 1973), H. serrata at 7 to 12 cm (Raodeo and Deshpande, 1981) and L. burmeisteri at 5 cm (Nair and Daniel, 1982).

Leefmans (1915) reported that majority of the grubs of L. rorida were seen 50 cm below the surface of soil. Rai et al. (1969) found that grubs of H. consanguinea remained in upper 15 cm of soil. Daniel and Kumar (1976) found the grubs of L. burmeisteri at 7.5 to 10 cm in moist soil and at 30 to 45 cm in dry condition. Veeresh (1977) observed the grubs of H. serrata at a depth of 10 to 40 cm. However, in June maximum number was seen at 20 cm, in July/August at 10 to 20 cm and in November/January at 20 to 30 cm. Jose and Kaul (1978) reported that the grub of H. serrata was confined to 15 cm depth of soil. Yadava (1981) found the grubs of H. consanguinea at 10 to 20 cm depth.

Lopez (1931a) reported that pupae of L. irrorata were found at a depth of 20 to 30 cm. Kalra and Kulshreshtha (1961) found pupae of H. consanguinea at 30 to 150 cm depth. Apostol and Litsinger (1976a)

found the pupae of L. irrorata at a depth of 80 cm. Veeresh (1977) found maximum number of pupae of H. serrata at 20 to 40 cm depth of soil.

Adults of H. consanguinea were seen at 15 to 75 cm depth of soil. After emergence adults were mostly seen up to 30 cm range (Rai et al., 1969). Jose and Kaul (1978) found adults of H. serrata up to 30 cm depth during March but during the period of adult emergence in December they were seen at 45 to 60 cm depth.

1.10 Factors governing vertical distribution and movement of the life stages of root grubs

Movement of the grubs of H. consanguinea in morning and evening depending on soil moisture and temperature was reported by Gupta and Avasthy (1957). Nirula (1958) observed that the distribution of the life stages of L. coneophora was influenced by the availability of soil moisture. The adults and eggs were seen in upper layers when soil was moist and in deeper layers in dry season. He also observed that the grubs remained near to the surface during early morning hours and during rainy season, compared to late noon hours and dry seasons, respectively. The vertical migration of the grubs at different periods of the day and at different seasons of the year was attributed to the moisture content of soil.

Shorey and Gyrisco (1960) found no pronounced change in vertical distribution of A. majalis until after drying had proceeded below the range of available soil moisture. Critical soil moisture level was found to be four per cent and above that level grubs showed no dominant choice up to 12 per cent. Kalra and Kulshreshtha (1961) did not find morning and evening movements in the case of the grubs of H. consanguinea. Mathen et al. (1964) also reported vertical migration of the grubs of L. coneophora at different periods of the year depending on soil moisture and temperature. Tashiro et al. (1969) found that when adequate moisture was available grubs of A. majalis occupied the upper 5 cm of soil where food occurred in abundance. Rai et al. (1969) found that the grubs of H. consanguinea remained in 15 cm layer having sufficient soil moisture and moved up and down depending on the moisture level of the soil. Valenta and Gavells (1970) found that the grubs of M. melolontha moved up from their over wintering sites (60 to 80 cm) when soil temperature reached 6°C. But when the temperature reached 9°C grubs were in surface layer at 0 to 20 cm. They observed that in autumn when temperature of soil at 0 to 20 cm reached 10°C they moved down. According to them the larval movement was determined by soil temperature, humidity and acidity. Fleming (1972) also found that vertical

movement of P. japonica was in response to change in the moisture and temperature. H. serrata was also reported to move up and down in soil depending on available moisture (Veeresh, 1977).

Distribution of the pupal stage was also reported to be correlated with temperature and moisture of soil. Depth at which pupae of A. majalis occurred in soil depended on moisture content and type of soil (Tashiro et al., 1969). According to Veeresh (1977) site of pupation of H. serrata varied with reference to the variation in temperature at different places. Jose and Kaul (1978) observed that from third week of December, grubs of H. serrata pupated at 45 to 60 cm depth and they further observed that fall in temperature rather than moisture brought about this behaviour of pupating grubs. Yadava (1981) also observed that pupation was directly related to the soil moisture and temperature.

1.11 Horizontal movement of root grubs

Horizontal movement of grubs was observed in the case of H. consanguinea (Kalra and Kulshreshtha, 1961), A. majalis (Tashiro et al., 1969), P. japonica (Fleming, 1972) and H. serrata (Veeresh, 1977). In all these cases the availability of food was attributed as the factor causing the migration.

1.12 Chemical control

1.12.1 Leucopholis coneophora Burm.

Application of five per cent chlordane at 28 lb/acre gave good control of grubs of L. coneophora (Nirula and Menon, 1957). Ten per cent BHC dust at one cwt/acre gave effective control of the larvae and was superior to DDT and there was no significant difference between the performance of different formulations of these pesticides (Nirula, 1958). Valsala (1958) reported that five per cent chlordane at 28 lb/acre or 10 per cent BHC at 56 lb/acre applied once a year after south west monsoon gave satisfactory control of the pest. Insecticides had to be tilled or ploughed to six inches depth in soil. Mathen et al. (1964) found that heptachlor was inferior to BHC, aldrin and chlordane and malathion was totally ineffective in the control of grubs. Johnson and Nair (1966) obtained best result with five per cent aldrin at 100 lb/acre but aldrin 50 lb and one per cent gamma-BHC at 100 lb/acre were ineffective. Abraham and Kurian (1970) concluded that five per cent aldrin, BHC or three per cent heptachlor at 120 kg/ha or 10 per cent chlordane at 60 kg/ha applied twice a year, in April and in August, effectively controlled the pest.

Abraham (1979) tested granules of carbaryl, carbofuran, phorate, quinalphos and thiodemeton at 4, 6 and 8 kg ai/ha. All the doses of all the insecticides were superior to control but reduction in grub population was as low as even 36 per cent only.

Veeresh *et al.* (1982) recommended drenching of soil with Chlordane 20EC 2 l/acre or Aldrin 30EC 2 l in 400 l water in the gap between the premonsoon showers and on the onset of monsoon in May-June for the control of *L. coneophora*.

1.12.2 Other species of *Leucopholis*.

Edgar (1958) reported that BHC 0.1 per cent spray was effective for the control of *L. rorida* in rubber nursery in Malaya. Rao *et al.* (1961) found satisfactory control of *L. lepidophora*, *L. burmeisteri* and a related species *Lepidiota* sp. in arecanut gardens with chlordane and heptachlor. Rao and Bavappa (1961) found that chlordane (Intox 8EC) at eight ounce in 100 gallons of water and 20 per cent of heptachlor at one ounce in one gallon of water used as soil drench gave good control of root grubs on areoanut.

Chlordane five per cent dust at 31 to 34 kg/ha, Heptachlor 20EC at 6.3 ml/100 l of water and BHC five

per oent dust 63.0 kg/ha were reported better for the control of areoanut white grub (Rao, 1963). According to Rao (1966) rubber plants in nursery oould be protected from L. rorida by pouring 0.1 per oent heptaohlor in 6-8 inches deep holes. Sheshadri (1969) found that phorate 8 g per arecanut palm gave 73 per oent kill of the grubs of L. burmeisteri and was superior to phorate 4 g per palm. Kumar (1974) used dimethoate, thiodemeton (Disyston and Solvirex), chlordane at 30 kg/ha, phorate at 15 kg/ha and carbofuran at 45 kg/ha. Mean number of grubs per plot ranged from 1.38 to 35.0 in treatment as against 82 in control. Dimethoate was the best followed by phorate. Apostol and Litsinger (1976b) reported that comparatively lower insecticide dosages were sufficient to control the first and second instar grubs than the third instar grubs of L. irrorata in Philippines. Lindane and chlordane at one kg ai/ha provided 100 and 90 per cent control, respectively, and were cheapest. Chlordane 4 kg and dieldrin 2 kg were equally effective but were more expensive.

Dimethoate 5 g at 30 kg, pongamia oil cake at 2000 kg, five per cent chlordane at 90 kg, five per oent BHC dust at 120 kg and quinalphos 1.5 per cent dust at 120 kg per hectare applied twice a year once just before the onset of monsoon and a second round in October

at the close of monsoon gave significant control of white grubs in arecanut gardens (Kumar and Daniel, 1981).

1.12.3 Holotrichia consanguinea.

Gupta and Avasthy (1957) found that 10 per cent BHC dust at 112 lb/acre gave 50 per cent reduction of the pest population in Bihar. Prasad and Thakur (1959) found that BHC at 15 lb/acre virtually gave no control of grubs. Kalra and Kulshreshtha (1961) tested BHC, aldrin, chlordane and DDT at 5 and 10 lb ai/acre as single application in May and two applications in May and July. A single application of BHC 10 lb caused 71.4 per cent reduction of grubs. Two applications proved more effective with 85.7 per cent reduction of grubs. Desai and Patel (1965) tested BHC, aldrin, chlordane and heptachlor and found that BHC 10 per cent at 40 lb/acre was superior to others. The mean test plant mortality was 5.7 in treated plots as against 10.3 in control plots. Kaul et al. (1966) worked out LD_{50} values of different chlorinated insecticides against third instar grubs and ranked them in the following descending order: toxaphene, chlordane, aldrin, BHC, dieldrin, heptachlor and gamma-BHC. Patel et al. (1967) recorded 54 per cent reduction in groundnut plant damage at 60 lb/acre of BHC while 80 lb/acre could not

protect more plants. Chlordane and heptachlor were less effective. Khanna et al. (1968) reported partial control of grub only with 10 per cent BHC at 50 lb/acre. Joshi et al. (1969) in a laboratory trial got 76 and 68 per cent mortality of third instar grubs with BHC 7.5 lb and heptachlor 8 lb/acre, respectively. Same doses of insecticides caused 86 and 80 per cent mortality of first instar grubs. Rai et al. (1969) reported that BHC 5 kg, aldrin 6 kg and heptachlor 6 kg/ha applied as dust were ineffective in checking pest damage. Sharma and Shinde (1970a) found that the LC_{50} of phorate was 0.02, heptachlor 0.20, lindane 0.625, chlordane 0.844 and aldrin 2.229 against the third instar grubs. Sharma and Shinde (1970b) found that pre-sowing application of phorate and heptachlor granules at 3 kg ai/ha checked the infestation on groundnut and the treatment was more effective than post-sowing application. Granules offered protection to the crop by repelling the grubs and by killing them. Srivastava et al. (1971) found that the application of phorate 10 G or dusts of 10 per cent BHC, 5 per cent aldrin and 6 per cent heptachlor at 25 kg/ha controlled the pest. Sharma and Shinde (1973) reported that phorate or disulfoton at 2 kg ai/ha protected pea plants but did not reduce larval population. Yadava and Yadava (1973) found phorate 2 kg ai/ha gave

maximum protection to groundnut plants. BHC and aldrin at 10 kg ai/ha were inferior to phorate. Kadu et al. (1976) found among the insecticides tested 10 per cent carbaryl at 125 kg/ha as most effective causing 63 per cent mortality of the grubs. Dwivedi et al. (1976) found that phorate and fensulfothion at 25 kg/ha effectively controlled the grubs. Prasad (1977) reported highest yield and lowest plant mortality of groundnuts and lowest larval population with 3 kg ai/ha of phorate. Yadava et al. (1977) found that phorate and fensulfothion were most effective for field control of the pest. Kadu et al. (1978) found that the grub mortality continued in field plots treated with BHC or carbaryl at 125 kg/ha for one month. Bhakatia and Sukhija (1978) reported fensulfothion, phorate and carbofuran at one kg ai/ha applied in furrows proved effective . According to Sukhija (1978) phorate 2 kg ai/ha was effective in controlling the pest. Vora et al. (1978) found that primiphos ethyl granules at 1.5 kg ai/ha was best for control of grubs. Srivastava and Mathur (1979) observed that among the various methods of chemical control the use of phorate granules was the best for the control of grubs, but being costly and uneconomic, it had not received wide acceptance. Sprinkling of chlorpyriphos (20 EC) in soil followed

by watering or flooding proved economical. Shinde et al. (1980) reported that based on LC_{50} values the relative efficacy of test insecticides was in the following descending order: quinalphos, phorate, carbofuran, disulfoton, heptachlor, endosulfan, lindane and aldrin. Nath and Srivastava (1980) determined the LC_{50} values of 10 insecticides to third instar grubs and found them in the following descending order: phorate, disulfoton, dieldrin, endosulfan, aldrin, lindane, heptachlor, BHC, chlordane and toxaphene. Vishwanath (1980) found 2.5 kg ai/ha of phorate reduced post population and increased the crop yield. Heptachlor and aldrin were also significantly superior to control. Srivastava et al. (1982) found seed treatment with carbofuran (50 FP) as a good method for protecting groundnut from the pest.

1.12.4 Holotrichia serrata.

David and Kalra (1966) found BHC at 4.5 lb ai/acre gave satisfactory control of the pest. Veeresh (1973b) reported that phorate 6 kg/acre gave effective control while heptachlor 6 per cent dust at 18 kg/acre was ineffective. Bhatnagar et al. (1975) recommended the use of Lindane 5 G at 50 kg/ha, fensulfothion or phorate at 25 kg/ha, for white grub control in groundnut field. Five per cent dust of heptachlor 175 kg/ha was

ineffective. Veeresh et al. (1976) found carbofuran at 0.75 kg and phorate 2.5 kg were effective in controlling the grube. Kushwaha and Noor (1976b) found mephospholan, phorate (2.5 kg ai/ha) and carbofuran (1.5 kg/ha) were superior to disulfoton and quinalphos (2.5 kg ai/ha). David et al. (1976) found an appreciable reduction of the grub population and increase in yield of sugarcane by the application of fensulfothion or quinalphos at 5 kg ai/ha during May/June. BHC 10 kg and dieulfoton, phorate and chlorfenviphos 5 kg ai/ha were ineffective. Veeresh (1977) reported that phorate 0.79 kg ai/acre uniformly applied before sowing of sugarcane, when the grubs were in the first instar, was effective. Application of insecticide at the grown up stages of the grubs did not prove satisfactory. Insecticidal application was not found effective against grubs under unirrigated conditions and in dry lands. Best results were obtained only when the plots were irrigated immediately after treatment. Jose and Kaul (1978) found BHC at 5 kg ai/ha gave reduction of pest but carbofuran was superior. Abraham and Rajendran (1978) recommended drenching with one per cent aldrin, chlordane or heptachlor around the base of rubber plants in nursery or soil application of 10 per cent BHC at 75 kg/ha for reducing the incidence

of H. serrata. Patil et al. (1981) found that the most effective dust treatment for control of grubs was BHC 10 per cent at 125 kg/ha. As granules five per cent diazinon, 10 per cent phorate or three per cent mephosfolan each at 25 kg/ha were the best for control of the pest.

Studies conduoted on the control of other Indian root grubs are meagre. Srivastava and Khan (1963) found aldrin 2 per cent and BHC 10 per cent dust at 100 lb/acre were effective against H. insularis. Venkitaramaiah (1969) reported good control of H. nilgiria with dieldrin and Telodrin. D'souza et al. (1970) found that Phorate 10 G and gamma-BHC applied to eight-month-old coffee seedlings afforded complete control of H. nilgiria but gamma-BHC caused marked yellowing of leaves. Chacko and Bhat (1974) found that the granules of fensulfothion, Disyston, dimethoate and phorate offered high mortality of H. nilgiria. Sachan and Pal (1974) found BHC + carbaryl (Sevidol) 2.5 kg ai/ha was superior to 10 per cent BHC or phorate 2.5 kg ai/ha for the control of H. insularis. Sachan and Pal (1976) reported that 10 per cent BHC, sevidol or chlorphyrifos gave 72 to 82 per cent reduction of grubs of H. insularis.

1.13 Management practices

1.13.1 Leucopholis spp.

Leefmans (1915) suggested rubbing red pods of Capsicum annum for attracting and trapping the beetles of L. rorida.

Otanes (1925) suggested hand collection of adults, ploughing and picking of grubs for control of L. irrorata. Uichanco (1930) did not agree to the hand collection of beetles. Otanes and Karganilla (1947), however, suggested collection of grubs, exposure of grubs for feeding by chicken and birds, collection and destruction of adults from host plant and promoting the parasite Campsomeriella aureicollis as effective methods for the control of L. irrorata. Rajamani and Nambiar (1970) suggested that good drainage would reduce the population of white grubs in arecanut gardens since the grubs were found in low lying areas where high water table existed or water logging conditions prevailed. Nair and Daniel (1982) recommended the removal of wild growth in the garden for the control of L. burmeisteri.

In the case of L. coneophora an integrated control schedule suggested by Kurian et al. (1974) included mechanical cum cultural methods like deep ploughing or digging of soil to expose immature stages to dessication

or predation by natural enemies like birds and mammals, attraction of adults to light and killing, exploitation of parasite Campsomeriella collaris F, nematode DD 136 and pathogens. Veeresh et al. (1982) suggested hand collection of adults, digging and destroying grubs around standing crops for the control of the pest in coconut gardens.

1.13.2 Holotrichia spp.

Avasthy (1967) suggested rotation of crops in endemic areas. Yadava (1981) suggested a management practice for the control of H. consanguinea involving the collection and killing of beetles, spraying the host plants with insecticides to kill the adults coming for feeding, collection of beetles by setting up light traps and killing them, ploughing of fallow land in August to expose the grubs, collection and destruction of grubs during inter-cultural operations, flooding the field, legislation for ensuring the adoption of beetle control measures by all farmers and insecticidal control of grubs when needed.

Veeresh et al. (1982) observed that control of H. serrata would be possible only when pest was managed from eggs to adult adopting several methods of control and any single method alone would not control the pest effectively.

1.14 Persistence of BHC in soil

Edwards (1966) reviewing the available literature concluded that it took 3 to 5 years for 95 per cent dissipation of lindane in soil depending on climate, soil type and cropping. Lichtenstein et al. (1971) reported that in USA it took 11 years for 95.5 per cent dissipation of lindane used as a single soil application at the rate of 10 kg/ha. But under tropical conditions BHC did not persist long. Agnihotri et al.(1974 and 1977) reported that 97.5 per cent BHC was degraded in 180 days and this rapid degradation was explained on the basis of higher ground temperature. Kavadia and Gupta (1976) found a comparatively longer persistence of BHC which extended up to 15/16 months in Rajasthan. Pal and Kushwaha (1977) also reported 88 per cent reduction in BHC deposits after five months of application in sandy soils of Jodhpur. Srivastava and Yadava (1977) reported a still faster degradation of BHC. They found that 70 to 90 per cent of BHC was lost in three months when applied at the rate of 5 to 30 kg/ha. They attributed this rapid loss from soil to quick volatilization.

1.15 Persistence of heptachlor in soil

Lichtenstein and Schulz (1959) found soil temperature as an important factor in the persistence of insecticides in soils. No insecticide loss was found in frozen soils. At a temperature of 6°C, 16 to 27 per cent of aldrin and heptachlor were lost within 56 days, whereas, 2 to 14 per cent of the initial insecticides alone was found after 56 days when held at 46°C. Wilkinson and Finlayson (1964) found the toxic residue of heptachlor nine years after treatment in silt loam soil in field. Wiese and Basson (1966) from South Africa, reported that prevailing weather conditions had marked effect on the rapidity of degradation. Knutson et al. (1971) found residue of heptachlor and heptachlor epoxide in Great plain soils, but there was no accumulation from year to year and about 95 per cent of the combined residues disappeared within a year after treatment. Guenzi et al. (1971) found that heptachlor decreased during 22 weeks where soil mixing was done and was flooded. But Stewart and Fox (1971) detected residues of heptachlor in Nova Scotia in 12 years after application. Harris and Sans (1972) showed that biological activity of heptachlor was completely lost in 16 weeks of application in Canada. Agnihotri (1978)

reported that dissipation of aldrin and heptachlor was higher under uncovered conditions than covered conditions. Eightythree per cent of heptachlor was lost in 120 days under unoovered conditions and only 63 per cent lost in covered conditions.

1.16 Movement of BHC and heptachlor in soils

Lichtenstein (1958) showed that gamma-BHC leached to some extent from treated soils downwards to untreated soil and such movements continued under non-leaching conditions also. Krzymanska and Macklewicz (1969) applied one per cent gamma-BHC at 1.5 kg/ha and raked into a depth of 7-10 cm. The percentage residue after one year at 0-10 and 10-20 cm was 23 and 25 per cent and after two years 17 and 16.8 per cent, respectively. Gawaad et al. (1971) carried out laboratory test to assess the leaching of gamma-BHC in three soil types by passing water and found that 29.71, 13.99 and 13.33 per cent of insecticide was lost from sandy, loam and sandy loam soils, respectively. Venkitaramaiah and Singh (1972) recovered residue of BHC even from a depth of 61-72 cm in field soils having a history of 20 years of BHC swabbing on coffee plants. Agnihotri et al.(1977) applied 10 kg ai/ha of gamma-BHC and heptachlor as dust and incorporated it to a depth of 0-15 cm.

There was no leaching of BHC or heptachlor beyond 0-15 cm.

Wiese and Basson (1966) reported that downward movement or leachability of insecticides was greater in light soils in the case of DDT, chlordane and heptachlor. Harris and Sans (1969) analysed soils from farms in which insecticides at different depths of the soil were being used intensively. They detected residues of aldrin, dieldrin, endrin, heptachlor, chlordane, DDT and dicofol. In cultivated soils the residues were retained in top 6 inches while in cultivated light mineral soils it was recovered up to 10-12 inches. They concluded that vertical distribution of residues in soil is dependent on the type of soil, the extent of cultivation and the characteristics of the insecticide. Knutson et al. (1971) found that heptachlor applied in soil cultivated with maize penetrated to a depth of 12 inches only. Stewart and Fox (1971) reported that heptachlor penetrated up to 10 inches when average rainfall reached 35 inches.

MATERIALS AND METHODS

MATERIALS AND METHODS

2.1 Biology of *Leucopholis coneophora* Burm.

2.1.1 Obtaining first instar grubs in the laboratory.

Beetles collected from field were used for this purpose. Mating pairs were collected in glass bottles half filled with moist soil and were brought to the laboratory. From these one female and four males each were liberated in breeding cages. Each cage consisted of 30 cm^3 dealwood box filled to three-fourth with loamy sand soil passed through a 20 mesh sieve and sterilised to eliminate fungi pathogenic to the eggs of soil insects (Wightman and Fowler, 1974). After releasing the beetles each cage was kept closed with a piece of nylon net held in position with a rubber band.

Eggs laid were collected daily passing the soil in the cage through a 20 mesh sieve. The eggs were kept in petri-dishes in batches of 5-10 and were covered with sterilized moistened soil. Water was sprinkled over the soil frequently to keep the same just wet throughout. The dishes were daily observed from the 20th day after incubation to record the actual date of emergence of grubs for assessing the period of incubation. Soon after hatching the grubs were transferred to garden pots filled with soil and planted with sprouted groundnut seeds. At the end of the third day, when they were sufficiently grown up for handling, they were collected from the pots and were used for various experiments.

2.1.2 Detailed biology of L. coneophora on coconut.

One hundred and fifty first instar grubs were transferred to three-month-old potted coconut seedlings at the rate of one grub per pot. The growth and moultings were being observed at two days' interval. From each instar ten specimens were collected and preserved for studying detailed morphological characters.

2.1.3 Larval morphology of L. coneophora.

Third instar grubs of L. coneophora reared in the laboratory as detailed earlier (2.1.2) were killed in hot water and put in 10 per cent KOH solution for four days. These were thoroughly washed in fresh water and kept in glacial acetic acid for ten minutes and then transferred to 1:1 carbolic acid acetic acid mixture for 15 minutes and finally to 1:1 carbolic acid xylol mixture. Then they were mounted on slides in canada balsam. Drawings were made using drawing head. Utilising the data available on the characters of L. lepidophora and L. burmeisteri (Veeresh, 1981) a key was prepared for the identification of the grubs of the three species including L. coneophora.

2.2 Effect of different host plants on the biology of L. coneophora

The plants used for the studies were raised in garden pots (30 cm dia). The bottom of the pot was cut out leaving

a rim of 10-15 mm around the edge. Twenty mesh galvanised iron net out out into a circular disc was placed inside the pot at the bottom and the same was fixed to the rim with cement mortar. The pots were then kept burried to three-fourth in the soil. This facilitated the maintenance of conditions in the pot similar to that of the field. The pots were then filled with loamy sand soil.

In the case of coconut, dehusked nuts having a tuft of fibres at the eyes were planted so as to have early rooting (Koshy and Sosamma, 1978). Crotalaria and cacao seeds were sown in the pots and in the case of cassava 15 cm long stem cuttings were planted. Coconut seedlings were used for the experiment three months after planting and in the case of cacao and crotalaria two months old plants were used.

Three-day-old grubs obtained from pots planted with sprouted groundnut seeds and kept in the laboratory (2.1.1) were released in field pots at the rate of one grub per pot and 200 such pots were set for each crop. When the plants in the pots faded due to feeding, the grubs were transferred to the fresh plants which were potted earlier and were being maintained for the purpose. On reaching the prepupal stage the grubs were transferred to fresh pots, half filled with soil. Each grub was placed in a small pit in the soil and was covered with an earthen dish over which further soil

was added. This prevented the formation of the earthen cell by the pupa and facilitated further observations on development. The pots were closed with nylon net held in position with rubber bands. When the adults emerged they were collected and each female was transferred to an egg laying cage along with four males for observing their longevity and fecundity as well as the viability of the eggs laid. The survival percentage and duration of the different life stages also were recorded.

The length and width as well as the weight of different life stages of L. coneophora, as influenced by different hosts were recorded using the stages obtained from rearings separately maintained for the purpose. Since the insect was being reared individually till the emergence of the adults, the grubs developing into males and females could be traced back and relevant data could be grouped accordingly.

2.3 Nature of damage caused by L. coneophora on different host plants

2.3.1 Cassava (Manihot esculenta Cranz.).

One third instar grub each was liberated in 50 pots planted with cassava setts at the rate of one sett per pot. Ten pots similarly planted and kept without exposure to the grubs served as control. All the plants were maintained with adequate irrigation. Another lot similarly planted and exposed to the grubs along with corresponding control

was maintained without irrigation towards the later stages to study the effect of irrigation on the infested crop.

Thirty days after treatment the symptoms visible on the aerial parts of the plants were recorded. The plant in each pot was then taken out carefully by washing out the soil with a gentle stream of water. The injury at the underground portions of the plants was observed and they were correlated with the aerial symptoms recorded earlier.

In the second experiment four-month-old plants raised in pots were exposed to the attack of second instar grubs at the rate of 1, 3 and 5 grubs per plant. There were 15 plants in each treatment and a set of 15 plants maintained without grubs served as control. The extent of injury was assessed at harvest ie. four months after the releasing of grubs. Plants were taken out carefully as done earlier and different growth parameters and the yield data were recorded.

Ten tubers from control plants and 10 damaged and undamaged tubers each from plants infested with the grubs were collected as three separate lots and the content of starch, amylose, amylopectin and hydrocyanic acid (HCN) in the edible flesh of samples were estimated, so as to assess the possible deterioration of the quality of the tubers due to the feeding of grubs.

Starch was estimated following the method of MacCready *et al.* (1950). Fifty mg of powdered, dried tuber was suspended in 50 ml of 80 per cent alcohol, boiled on a water bath, evaporated to 10 ml and decanted after centrifuging. The residue was dissolved in 15 ml of 52 per cent perchloric acid and made up to 100 ml with deionized water. One ml of the aliquot was taken in a test tube diluted to 5 ml and colour was developed by addition of 10 ml of anthrone reagent and heating for 7.5 minutes at 100°C in water bath. The OD was measured in Beckman Model-26 Spectrophotometer at 630 nm. Glucose was used as the standard.

Amylose was estimated by the method of Gilbert and Spragg (1964). One hundred mg of cassava flour was shaken in 10 ml, 1N NaOH and the volume was made up to 100 ml. One ml of aliquot was transferred to a 50 ml volumetric flask and neutralised with 1 ml of 10N HCl, followed by 1 ml of 10 per cent potassium hydrogen tartarate, volume was made up to 45 ml and 0.5 ml iodine solution was added. Final volume was made up to 50 ml. After 20 minutes the OD was measured at 680 nm. Pure amylose was used as the standard. Quantity of amylopectin was found by deducting the quantity of amylose from total quantity of starch.

The estimation of HCN was done by the method described by Indira and Sinha (1969). One g of flesh tuber was homogenized in 25 ml water and was taken in a 500 ml conical flask. The flask was closed with a rubber cork, having a Whatman No.1 filter paper strip soaked in alkaline sodium picrate and suspended from the bottom side. After 18 hours the flask was transferred to an oven maintained at 60°C. Thirty minutes later the filter paper strip was taken out and eluted in 20 ml distilled water. Absorbance of the elute was recorded on a Beckman Model-26 double beam Spectrophotometer at 540 nm. KCN was used as the standard.

Palatability test was also carried out to assess the consumability of the tubers partially damaged by the pest. The tuber samples were peeled and sliced to uniform size and were cooked in same quantity of water and under identical temperature and boiling time. Palatability of the preparations was checked by a taste panel consisting of ten individuals.

2.3.2 Cacao (*Theobroma cacao* L.).

Five-month-old cacao plants raised in pots as described earlier were exposed to the feeding of second instar grubs of *L. conicephora* at the rate of 1, 2 and 3 grubs per plant. Each treatment had 15 replications.

Fifteen plants maintained without grubs served as control. At the end of 45 days the plants were taken out of soil and the different growth parameters were recorded.

2.3.3 Wild sunn-hemp (Crotalaria striata DC.).

Wild sunn-hemp plants raised in pots were exposed to the second instar grub of L. coneophora at the rate of one grub per plant (higher levels of pest population killed the plants outright). The plants used were 45 days old. Fifteen plants each were maintained for the treatment and control. At the end of 45 days after the introduction of grubs the different growth parameters of the plants were recorded.

2.3.4 Coconut (Cocos nucifera Linn.).

Since it is a perennial crop and the manifestation of symptoms by pest infestation would appear with a long lapse of time, the nature of damage caused by L. coneophora on the crop was restricted to field observations in the nursery and in grown up plantations.

2.4 Distribution of the different life stages of L. coneophora in different depths of the soil and their seasonal occurrence.

2.4.1 Assessment of the population.

The population was assessed at fortnightly intervals at two locations in Alleppey District viz. Thazhakkara and Vazhuvadi from September, 1977 to September, 1980. At each

location an infested plot of 0.5 ha was identified and in the plot, ten (1 m^3) pits were taken, three metres away from the bases of the palms. The soil in the pit was removed in layers and the same was passed through a 20 mesh sieve to separate out the life stages of the pest present. The number of eggs, different instars of grubs, pupae and adults present in layers of 0-15, 15-30, 30-45, 45-60 and 60-100 cm depths were recorded. Using these data the seasonal occurrence of the pest and their distribution in different depths of soil were assessed.

2.4.2 Assessment of soil temperature and moisture.

The temperature of the soil at each of the above depths excepting 60-100 cm was recorded, from the middle of each layer using Wilh.Lambrecht soil thermometers. Samples of soil collected from each depth were dried to constant weight in an oven maintained at 70°C and from the data the moisture percentage in each sample was estimated. The rainfall in the location was recorded using a FRP rain guage. The above data were collected for a period of three years from September, 1977 to September, 1980 at Thazhakkara.

2.4.3 Influence of soil temperature and soil moisture on the distribution of life stages of L. ooneophora.

The soil temperature in ranges of 2°C was plotted against the moisture content in ranges of two per cent on a graph and the number of the different life stages of

L. ooneophora observed in different ranges of temperature and moisture (irrespective of the depths of soil in which they were present or months of the observation) were recorded in the graph so as to give a box diagram. The data relating to the beetles and larval instars in consecutive years were treated as replication and the analysis of variance was done. From the results the ranges of temperature and soil moisture preferred by the different larval instars and adults could be identified.

2.5 Adult emergence and factors influencing it

The period of emergence of the adult beetles from the soil, the period of activity of the emerged insects and the sex ratio of the emerging beetles were studied by making regular collections of the beetles for three years from 50 m^2 area of a heavily infested field. Rainfall and soil temperature in the area also were recorded.

2.6 Chemical control

2.6.1 Relative efficacy of insecticides.

Relative toxicity of four insecticides viz. aldrin, BHC, chlordane and heptachlor against second and third instar grubs of L. ooneophora was assessed. Five per cent dust formulations of these insecticides were applied in field in 1 m^2 plots. The insecticides were raked into soil up to a depth of 15 cm. Each dose was applied in three plots.

At the end of 24 hours after application, soil samples from the different plots were collected from a depth of 0-15 cm, using an auger of 7.5 cm dia. Ten such samples taken from each plot were mixed. Ten jam jars of 250 ml capacity were half filled with the sample taken from each plot. Presoaked groundnut seeds were kept buried in the soil as food for grubs. Field collected grubs of required age and uniform size were liberated, one in each bottle. Observations on mortality, paralysis and normalcy were recorded at the end of 72 hours. Paralysed grubs were also treated as dead. The experiment was repeated using graded concentrations of each insecticide till a mortality range suited for the assessment of the LD_{50} values of the insecticides was obtained. Data were corrected for control mortality using Abbott's formula (1925). The corrected percentage mortality was subjected to probit analysis (Finney, 1952).

2.6.2 Field evaluation of the efficacy of insecticides.

The relative efficacy of BHC and heptachlor under field conditions and during different periods of the year was evaluated through a separate experiment. Cement tubs of 1 m diameter and 1 m height were used for the experiment. The tubs kept in open field were filled with soil. First instar grubs collected from field and kept under observation for three days were liberated in all the tubs commencing from June and at fortnightly intervals. This was continued

throughout the period of occurrence of the first instar grub in the field. Sprouted groundnut seeds were planted in the tubs which served as food for the grubs. BHC at 5 kg ai/ha and heptachlor at 1.4 kg ai/ha were applied as five per cent dust. The dust was mixed thoroughly with the soil in tubs up to a depth of 15 cm. For the assessment of most suitable period for the application of the insecticide each insecticide was applied in four treatments varying the time of application. The periods of treatment tried were in (a) April alone, (b) June alone, (c) April and August and (d) June and September. Each treatment was replicated thrice. Untreated checks were also maintained. The liberation of the grubs in the treatments subsequent to insecticidal application was done by putting them in 30 cm deep holes made in the soil so as to avoid the grubs coming in direct contact with insecticide treated top soil at the time of liberation.

The effect of the treatments on the pest was assessed in terms of the number of grubs reaching the third instar and pupal stages as observed at the end of December and May, respectively, the normal period by which all the grubs reach the above stages in field.

One month after the last round of the insecticidal application ie. in October, all the tubs were uniformly planted with germinating groundnut seeds at the rate of 25 seeds per tub. The mortality of plants in treatments

also served as an index of the efficacy of treatments since it was correlated with the activity of the grubs surviving in various treatments during the period.

2.6.3 Assessment of persistence and vertical movement of insecticides in soil.

The experiment was conducted in a field where no insecticide application was done earlier. Soil in the experimental plot was loamy sand, dark grey coloured with 63 per cent coarse sand (2 to 0.2 mm), 22 per cent fine sand (0.2 to 0.02 mm), 5 per cent silt, 9 per cent clay and 0.5 per cent organic carbon. The pH of the soil was 6.3.

Plots of 3 m^2 area were prepared with bunds all around and leaving 1.5 m as boarder. BHC at 5 kg ai/ha and heptachlor at 1.4 kg ai/ha were applied as five per cent dust. Application of the pesticides was done as in the previous experiment (2.6.2). Soil samples were collected with a tubular soil auger from 0-7.5, 7.5-15, 15-30, 30-45 and 45-60 cm depth, 24 hours after the insecticidal application and then at intervals of 30 days. Ten such samples were taken from each plot. The samples were separately dried under shade.

BHC present in soil samples was estimated following the colorimetric method developed by Schechter and Hornstein (1952) as modified in AOAC (1965) and also by bioassay technique and heptachlor residue was estimated with bioassay alone.

Extraction of insecticide.

From each sample 100 g soil was taken in 500 ml conical flask and 200 ml acetone was added to it. It was shaken for 30 minutes in a shaker and then filtered over anhydrous Na_2SO_4. Volume of extract was made up to 200 ml. One hundred ml extract was used for chemical assay and remaining 100 ml for bioassay studies.

Clean up.

The sample of 100 ml was concentrated to 10 ml passing air with a manifold evaporator. Five ml of this was taken in a long necked conical flask and was dried with the evaporator. The residue in the flask was dissolved in 15 ml glacial acetic acid. Then 2 g melonic acid was added. Content was refluxed on a sand bath for 45 minutes.

Determination of insecticide.

Five ml nitration mixture (1:4 HNO_3 and H_2SO_4) was taken in a test tube kept in an ice bath. The delivery tube of the Hancock and Laws apparatus was dipped in the nitration mixture. One g zinc dust was added into the long necked conical flask containing the cleaned up extract of insecticide and the flask was connected to the condenser of the above apparatus and then heated on a water bath. Refluxing continued for 90 minutes and the benzene evolved from the insecticide

residue was collected in nitration mixture and got converted to m-dinitrobenzene. After 90 minutes the nitration mixture was transferred to 250 ml separating funnel in which cold distilled water, 20 g crushed ice from distilled water and 40 ml ethyl ether were added. After shaking for 10 minutes the aqueous layer was transferred to another separating funnel and was rewashed with ether and ether layer was transferred to the first separating funnel. Then the ether was washed three times with two per cent aqueous sodium hydroxide and again washed with saturated solution of sodium chloride, twice. Then the ether layer was transferred to an Erlenmeyer conical flask passing through a filter funnel having a plug of cotton over laid with anhydrous sodium sulphate. 0.1 ml of mineral oil was added to the content of the flask. Ethyl ether in the flask was evaporated using a Snyder column till 2-3 ml of the material in the flask remained. This was again dried by swirling the flask. The m-dinitrobenzene present in the flask was dissolved in 10 ml ethyl methyl ketone. Two ml of the aliquot was taken in a test tube and was diluted to 10 ml with ethyl methyl ketone. 0.5 ml of 40 per cent KOH was added and the mixture was shaken vigorously for two minutes and kept in darkness for eight minutes. Violet red colour developed was read in spectrophotometer at 565 nm using ethyl methyl ketone as reference. The amount of BHC

in the extract was determined with reference to a regression equation derived by using technical grade of the insecticide.

Regression equation for estimation of residue.

Technical grade of BHC was diluted in acetone to give concentrations of 20, 40, 60, 80 and 160 /ug of the insecticide and taken in long necked flasks. Colour was developed following the procedure described above. From the transmittance caused by different concentrations of the insecticide the regression equation was worked out. The regression equation obtained was

$$y = 0.0101 + 0.0028x,$$ where

y = transmittance and

x = concentration of insecticide in ppm.

Recovery test.

Samples of 50 g soil were taken in 200 ml beakers. A stock solution of technical BHC was prepared in acetone having a concentration of 10 /ug per ml. Required quantities of this stock solution were added to the soil samples taken in the beakers so as to give graded concentrations of 10, 50 and 100 /ug of the insecticide per sample. One lot mixed with acetone alone served as control. Additional quantity of acetone was added to the beakers to keep the soil completely immersed. The samples were kept overnight and the insecticide was extracted and the quantities were

determined colorimetrically as described earlier. From the data percentage of the insecticide that could be recovered was calculated. The recovery for the above technique was found as 82-85 per cent.

Bioassay of insecticide

Rearing of test insect.

Adults of Drosophila melanogaster Meig. were used as test insect for the bioassay of residues of BHC. The insect was reared in the laboratory from a single pair of insect under a constant temperature of 25°C. The rearing medium consisted of agar 25 g, corn flour 75 g, jaggery 65 g, yeast 3.5 g, vitamin B tablets 15-20 numbers, propionic acid 2 to 4 ml and distilled water 1000 ml.

Preparation of the residue film in bioassay tube, exposure of test insect and assessment of mortality

Dry film method was used for the determination of the residues. One hundred ml of the extract prepared earlier was cleaned by passing the same through a column containing four cm layer of absorbent mixture (1 charcoal : 1 celite), over a three cm layer of anhydrous sodium sulphate held by glass wool. The extract was taken in a volumetric flask and volume was made up to 100 ml. One ml of the extract was evaporated in a bioassay tube of 30 mm dia and 250 mm length. The tube was kept rotating during the evaporation of the extract to ensure the spread

of the insecticide deposit uniformly on the inner surface of the tube. After evaporation of the solvent the tube was kept open for sufficient period to get the fumes of the solvent removed. Twentyfive adults each of D. melanogaster (24 hour-old) were introduced in the bioassay tubes. The flies were not sexed. The tubes were closed and maintained at a constant temperature of 25°c. There were three replications for each treatment. Mortality or paralysis was recorded at the end of 18 hours. Flies exposed in tubes treated with acetone alone served as control.

Preparation of regression equation for residue estimation.

The mortality of D. melanogaster on dry films of technical grades of BHC 2, 3, 4, 5 and 6 ppm was assessed. The mortality was corrected using Abbott's formula. The data were subjected to probit analysis (Finney, 1952) and a regression equation was worked out. The regression equation obtained was

$y = -1.0245 + 3.8238x$, where

y = the probit mortality and

x = concentration of insecticide in ppm.

Estimation of BHC residue in samples.

Using the mortality of the test insects exposed to the dry films in the bioassay tubes the quantity of insecticide residues in samples could be estimated using the above

regression equation. Recovery test was done as in chemical assay and the extent of recovery obtained was 80-82 per cent.

Determination of heptachlor.

Heptachlor in the soil samples collected at different intervals could be determined by bioassay only. The insecticide was extracted from soil by the method described by Carter and Stringer (1970). Fifty g of dry soil was extracted for two hours on a shaker with 150 ml of 2:1 hexane isopropyl alcohol mixture. The extract was filtered and washed three times with 40 ml each of distilled water. Hexane layer was separated and filtered. Then it was passed through a column packed with activated charcoal, celite 545 and sodium sulphate. The insecticide in the extract was estimated using D. melanogaster as test insect, as was done in the case of BHC. The regression equation derived by using the technical grades of heptachlor was

$$y = 0.9284 + 2.5624x,$$ where

y = the probit mortality and

x = concentration of insecticide in ppm.

The extent of recovery of the insecticide following this method was found to be 97-99 per cent.

RESULTS

R E S U L T S

3.1 Biology of Leucopholis coneophora Burm.

3.1.1 Oviposition.

Eggs were seen laid in moist soil. Prior to egg laying the female beetle extruded its vagina which helped to form bulbous egg chambers in soil. After laying one egg the vagina was withdrawn. This process continued till the egg laying was completed. Occasionally eggs were seen in soil without any egg chamber also.

3.1.2 Egg.

Eggs, when freshly laid, were white in colour with an yellow tinge; spherical, oval or elliptical (Plate Ia); chorion smooth and coriaceous. As development progressed colour of the egg changed to dirty white and the mandibles of the developing embryo became visible as black spots.

Chorion of the freshly laid egg was fragile and broke along the lower margin if kept on dry surface. This did not happen on a wet surface. One-day-old eggs did not burst even on dry surface. Prolonged exposure to dry conditions caused the shrivelling of the eggs. Mean length of just laid eggs was 4.49 mm (range 4.32 to 4.8 mm); mean width 2.95 mm (range 2.72 to 3.04 mm) and mean weight 0.0194 g (range 0.0173 to 0.0203 g). At the time of hatching,

Plate I. Life stages of L. coneophora.

a) eggs

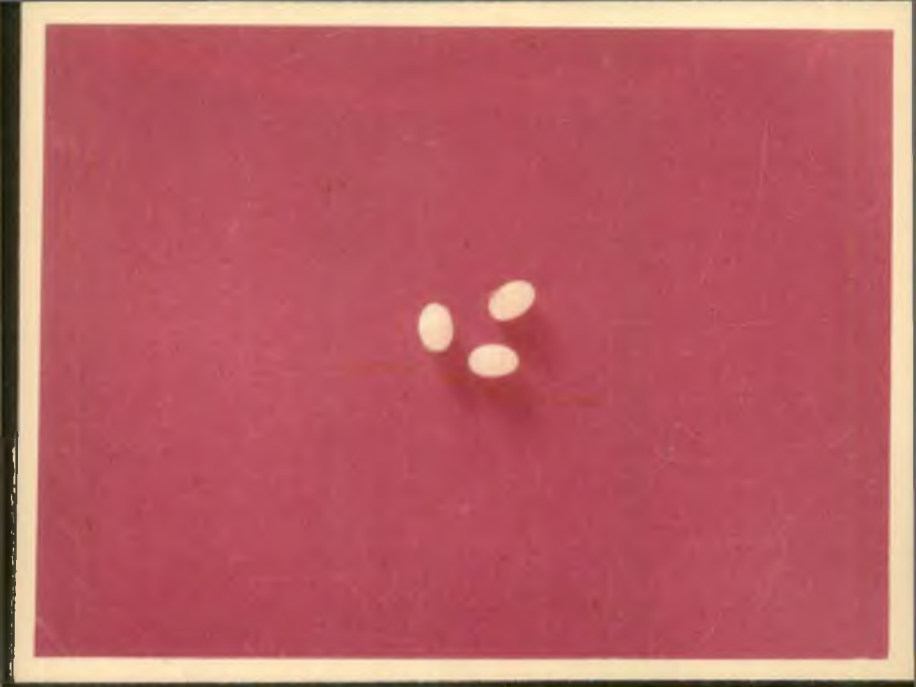
b) first, second and third instar grubs

a

b

a

b



a

b

the size increased to 5.90 mm (range 5.60 to 6.08 mm) in length, 4.64 mm (range 4.32 to 4.96 mm) in width and 0.0718 g (range 0.0641 to 0.0795 g) in weight. Size of the egg (Fig.1) increased from the third to the ninth day of incubation and then remained more or less constant while the weight increased up to the fifteenth day. Eggs collected from field and which were about to hatch had the size and weight of similar stage obtained in the laboratory. The incubation periods of eggs laid by beetles collected from the field and by those reared in the laboratory on coconut roots were found to be 23 days.

3.1.3 Grub (Plate Ib).

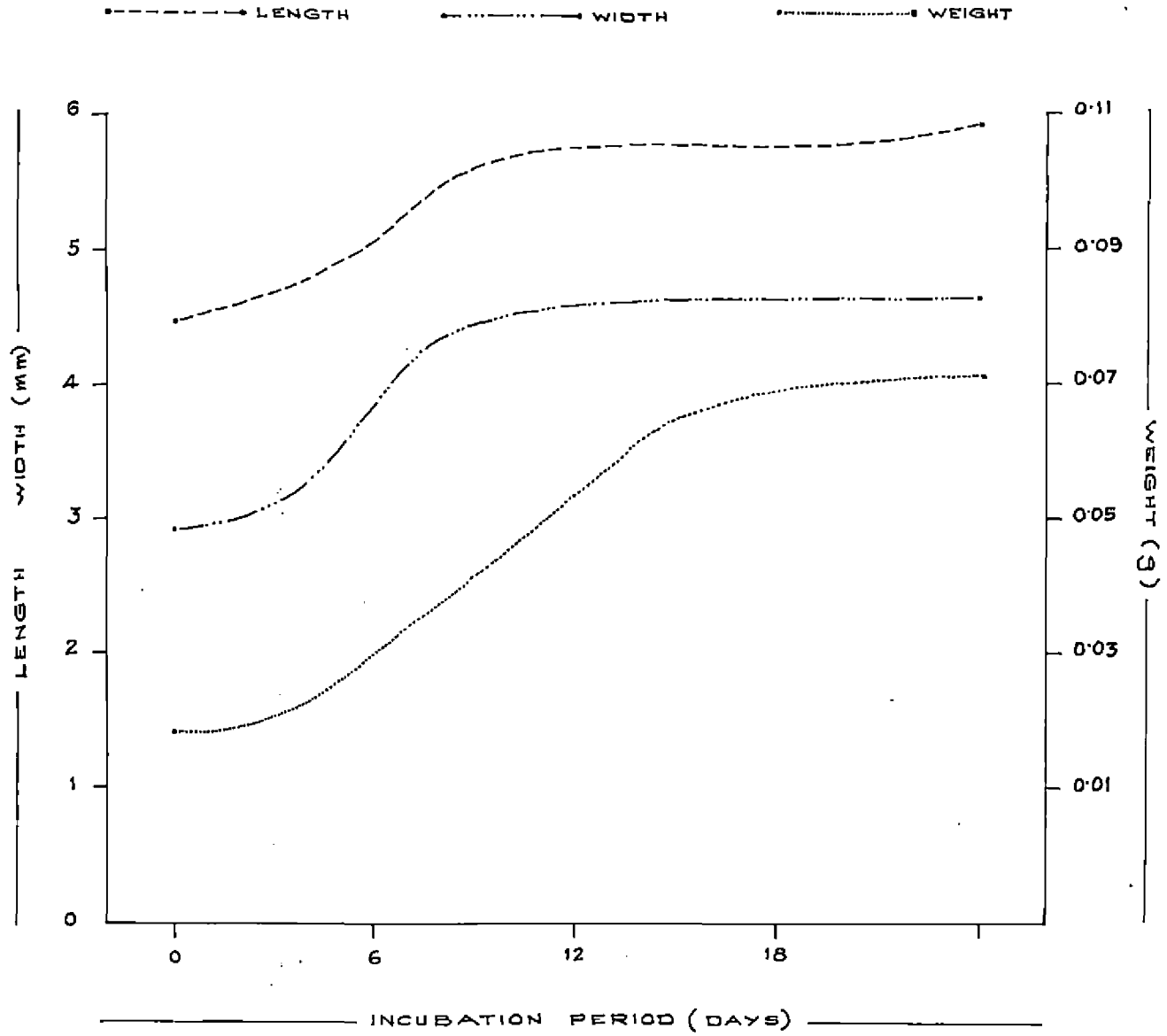
First instar grub.

The freshly hatched grubs were semitransparent, but within a day or two the colour became bluish white and the head and appendages turned brown. On hatching, the male grubs were 14.6 mm (range 13 to 15 mm) long, 2.95 mm (range 2.75 to 3.20 mm) wide and 0.0574 g (range 0.0469 to 0.0680 g) in weight. The female grubs were 14.8 mm (range 13 to 17 mm) long, 2.99 mm (range 2.7 to 3.2 mm) wide and 0.0592 g (range 0.0447 to 0.0634 g) in weight.

Head: prognathous, slightly declivent; mandibles reddish brown with black apices. Maxillary and labial

Fig. 1. Increase in the size and weight of the eggs of L. coneophora during the period of incubation.

FIG. 1.


LENGTH
WIDTH
WEIGHT
LENGTH WIDTH (mm)
WEIGHT (g)
0
1
2
3
4
5
6
0·01
0·03
0·05
0·07
0·09
0·11
0
6
12
18
INCUBATION PERIOD (DAYS)

palpi light brown, with a honey brown tinge towards the apices. Frons, face and vertex brown, with a few scattered silvery setae, smooth and shiny and with a few deep punctae on the frons and face and finely sculptured on the vertex and occiput. The head capsule width was 3.19 mm (range 3.13 to 3.34 mm). Mandibles nearly as long as the head minus the clypeus, light brown towards the base, reddish brown towards the middle, ebony black towards the apex and had a dark spot at the base; each with two teeth, one strong and pointed apically and other short and blunt, situated towards the base. Clypeus, slightly darker than the head and concolorous with the face, apical margin provided with fine brown setae. Antennae concolorous with head, four-segmented, second segment one and a half times as long as the first, third segment as long as the first and the terminal segment slightly swollen and subequal to the first; apex of the terminal joint with a brown tinge. Antennae inserted postero-lateral to the mandibles and the face.

Thorax: apices of legs and dorsal aspect of thorax brown, setae silvery brown. Rest of the thorax yellowish white, segmentation indistinct; Spiracles distinct and brown in colour. First thoracic spiracle, oval, remaining ones with a reniform appearance, testaceous brown in colour.

Abdomen: mostly white but dorsal aspect of abdomen up to the seventh tergite light brown; last abdominal segment bluish white, with numerous setae. Pali were 23-26.

The duration of the first instar grub varied from 34 to 46 days with a mean of 40.3 days for males and 38 to 51 days with a mean of 40.9 days for females.

Second instar grub.

At moulting to second instar, the grubs were cream coloured and soft. It was inactive during the first day after moulting and body gradually became more sclerotized. The second instar male grub had a mean length of 24.85 mm (range 22 to 27 mm), mean width of 5.5 mm (range 3.5 to 6.0 mm) and mean weight of 0.4890 g (range 0.3600 to 0.6050 g). The mean length of female was 24.75 mm (range 22 to 27 mm), mean width 5.7 mm (range 5 to 7 mm) and mean weight 0.4781 g (range 0.3710 to 0.7080 g).

Head: prognathous, with a slight tilt downwards, brown, smooth and shiny with a few punctae mostly in the anterior one third of the vertex, with yellowish brown pubescence arising from these shallow pits. Basal half of the frons concolorous with clypeus, but slightly darker. Mean head capsule width was 4.84 mm (range 4.37 to 5.21 mm). Mandibles brown to reddish brown at the

base and black at the apical half, apex ending in a strong tooth also having a blunt small dentation at the middle of the black area, situated in the inner aspect. Clypeus honey brown, thickly pubescent particularly at the apex, setae honey brown with a golden tinge. Labium yellowish light brown, with two-jointed palpi. Maxillary palpi brown, three-jointed, with very strong spines on the lacinia. Eye spots, dark reddish brown, situated at the base of the mandibles and subtended on either side at the base of the vertex and frons. Antenna light brown, four-segmented, arising near the base of the mandibles, first and third segments subequal, second longer than the rest and fourth being the shortest.

Thorax: transparent white with light brown patches towards the anterior side, setae light brown. Legs light brown with concolorous setae. Spiracles auricular, prothoracic spiracle the largest and nearly twice as big as others, the remaining eight abdominal spiracles subequal in size. Colour testaceous brown.

Abdomen: white with a dark slate blue colour towards the middle aspect; abdominal tergite provided with short spinaceous hairs all over the apical end with a golden honey brown tinge; distal half of abdomen nearly smooth, shiny with very few long setaceous hairs, the dark entrails seen through the transparent body wall giving the area

a brownish black appearance; apex of the abdomen provided with dense setae which are longer than those on the anterior abdominal tergites.

The second instar grub fed well on coconut roots and males moulted in 51.6 days (range 45 to 60 days) and females in 51.6 days (range 40 to 57 days).

Third instar grub.

The just moulted grub was creamy white with a brownish tinge on the dorsal aspect at the proximal half and slate coloured with a greyish tinge at the distal half of the abdomen. Just before prepupation they were 48.8 mm long (range 42 to 52 mm), 13.9 mm wide (range 13 to 15 mm) and 3.42 g in weight (range 2.67 to 4.98 g) for males and 56.3 mm long (range 52 to 60 mm), 16.3 mm wide (range 15 to 17 mm) and 5.68 g in weight (range 4.78 to 6.65 g) for females.

Head: reddish brown, vertex and occiput somewhat smooth and shiny with a few long scattered setae inserted in shallow punctae with a faintly leathery sculpture, frons microsculptured,irregular and distinct and face with a rough leathery sculpture. Head capsule mean width 7.71 mm (range 7.08 to 8.13 mm). Mandibles strong, yellowish brown, with a reddish tinge at the base, black apical half, ending apically in a strong tooth.

Running from behind to the middle of the inner aspect of the mandible is a ridge ending in a blunt tooth subtending anteriorly a few tubercular projections and in the inner aspect with a few blunt teeth. Clypeus attached to the face with a distinct narrow area which is light yellow with a greyish tinge, rugoso-reticulately sculptured with two foveae one on either side beset with very prominent honey brown setae. Labium, very prominent with two-jointed palpi, with an iridiscent red and blue lustre. Maxillae, with very prominent swollen cardo and galea beset with pronounced black dentation. Maxillary palpi three-jointed, the middle joint being smaller than the rest. Antennae inserted behind the mandibles, four-jointed, yellowish brown with a reddish tinge, first three segments subequal and the apical segment half the length of the preceding three joints.

Thorax: creamy white with yellowish tinge. Prothorax with a pair of coloured chitinized patches on either side. The anterior one large, light brown in colour and somewhat reniform in shape. Legs yellowish brown, bearing thick protuberance armed with very stiff spinous setae distributed all around. Tarsus ends in reddish brown claw, black in the middle. Coxa nearly white; trochanter indistinct; femur most prominent; tibia shorter than the tarsal joints, which are thick,

swollen and distinct. The prothoracic spiracles dark brown and nearly round, cribiform and nearly twice the size of other spiracles. Among the abdominal spiracles first two rounded oval and others round. Segments beset with brownish hairs.

Abdomen: with ten tergites well defined, first eight comparatively narrow creamy white and bearing spiracles; the apical two bare, smooth and shiny, dark slate coloured and without spiracles. The abdominal apex beset with brownish setae which have a golden yellow tinge.

Grubs bite strongly with the mandibles when handled. A black fluid also was seen ejected through mouth while biting. The grubs coming in contact fought among themselves often leading to the death of all the individuals involved. The grubs moved in tunnels on their legs or on their back. When kept out of soil they moved on their back only.

The full grown grub turned deep yellow. They then stopped feeding, constructed a boat shaped chamber in soil. The changes in the colour and behaviour indicated full maturity of grubs. Walls of the chamber were smooth and firm. Grubs lay on their back and became inactive. The body then gradually shrunk, intestinal content was voided and it entered the prepupal stage. The prepupa was deep yellow and it changed into the pupa in 4 to 8 days.

Duration of third instar grub including the prepupal period was 168.1 days (range 155 to 173 days), for males and 177.5 days (range 164 to 189 days) for females.

Total larval period from the date of hatching of eggs to pupation was 260 days (range 249 to 269 days) for males and 270.0 days (range 257 to 281 days) for females.

3.1.4 Pupa (Plate II a and b).

Fresh pupa was light brown in colour and as development progressed the colour gradually turned to deep brown. A few days before emergence of the beetle, the pupa became blackish brown. Pupa was exarate and lay on its back in the earthen pupal chamber. Male pupa measured 31.3 mm in length (range 30 to 34 mm), 15.0 mm in width (range 14 to 17 mm) and weighed 2.35 g (range 2.06 to 2.63 g), whereas the female pupa was 35.5 mm in length (range 34 to 38 mm), 16.8 mm in width (range 16 to 18 mm) and 4.28 g in weight (range 3.85 to 4.63 g).

Pupal period was 25.3 days (range 23 to 29 days) in the case of males and 25.7 days (range 23 to 29 days) for females. All pupae removed from the pupal chamber and kept covered with loose soil died.

Total life period, from egg to emergence of adult, of male was 308.3 days (range 295 to 317 days) and of female 318.7 days (range 304 to 333 days).

Plate II. Life stages of L. coneophora (continuation).

a) pupa - ventral view
b) pupa - dorsal view

c) beetles - left: male, right: female

a

b

c

3.1.5 Adult (Plate II c).

The body of the newly emerged adult was soft and greyish white in colour. Subsequently, in 3 to 4 days body became hardened and the colour turned to deep greyish brown and head black. The male measured 26.8 mm in length (range 26 to 28 mm), 13.6 mm in width (range 12.5 to 16.0 mm) and mean weight was 1.69 g (range 1.34 to 2.10 g) and the female measured 30.9 mm in length (range 27 to 32 mm), 16.9 mm in width (range 13 to 18 mm) and mean weight was 3.16 g (range 2.72 to 4.21 g), respectively. Longevity of male beetle was 42.3 days (range 36 to 50 days) and that of female was 42.6 days (range 37 to 50 days).

Antennal club of female was 1.62 mm long and 0.803 mm wide and that of male was 2.55 mm long and 0.86 mm wide.

Emergence of adults from soil.

Male beetles emerging out of the pupal chamber, on maturity, came upwards pushing up the soil. They remained for a short time with the head and prothoracic legs protruding from the soil surface and facing the sky. The antennae were also held out in an erect position with the lamellae stretched out. Gradually they came out of the soil and took to wings with a 'buzzing' sound,

leaving a circular emergence hole of about 12-14 mm in diameter on the soil surface (Plate III). Numerous such holes could be noticed on the ground during the emergence season in the infested area. Females seldom flew or made such emergence holes. They remained in soil with their antennae and part of the head protruding.

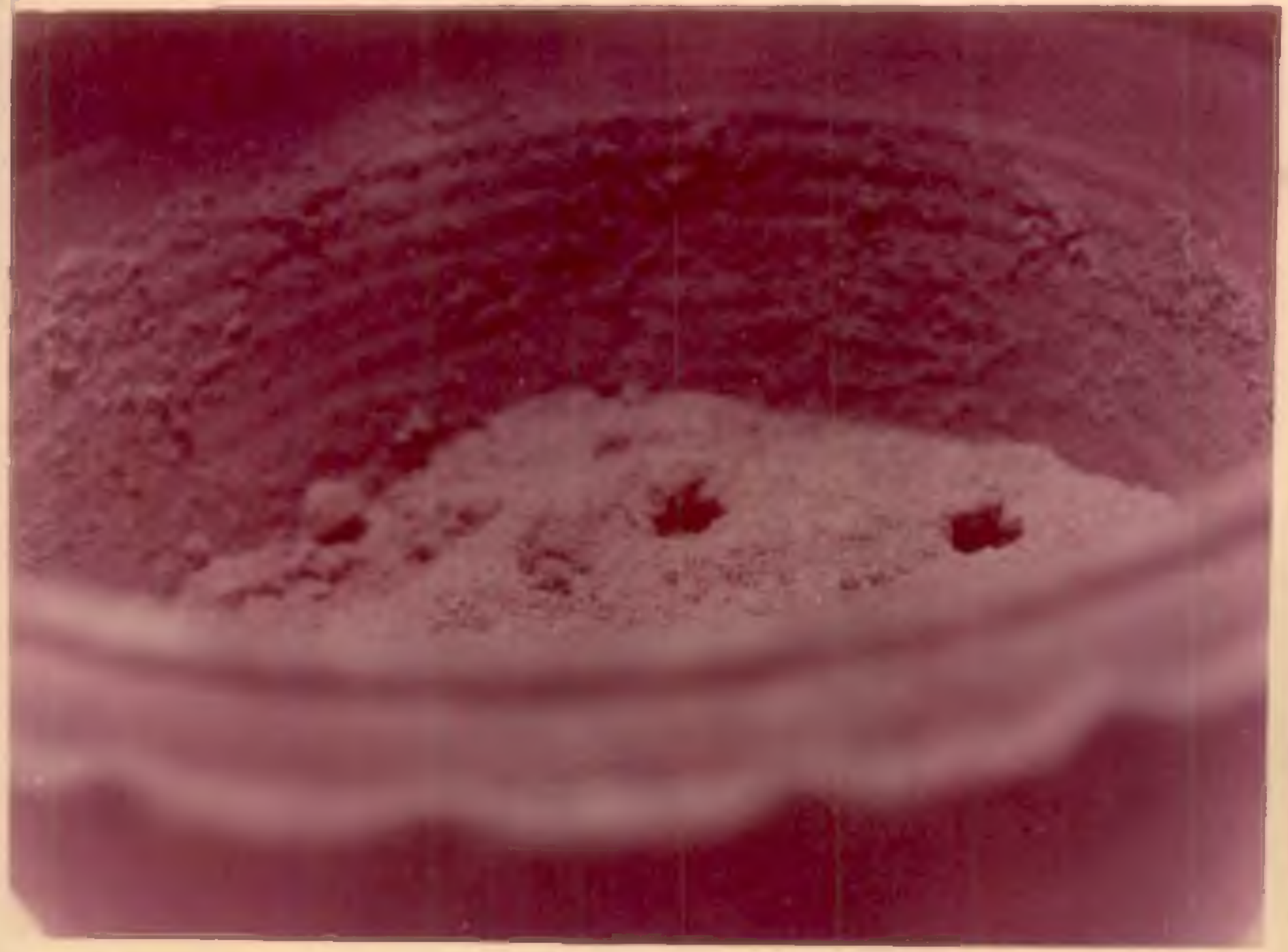
Sex ratio of male to female collected from field was 1 : 0.099 and ratio observed in the laboratory was 1 : 0.734. The beetle emergence was at dusk around 6.45 pm and they were on their wings for 25-35 minutes.

Mating.

The males in flight located the females in the ground and alighted in the vicinity and then crawled to them. When the female came in contact with a male, it came out of soil and the male was seen mounting for copulation. A little later the male fell on its back and in line with the female. But the mating continued. After three minutes the female started digging the soil and she crawled in dragging the male also with her. Mating continued for about 7-9 minutes. During the peak period of emergence several males could be seen clustering around each mating pair and attempting to mate with the same female.

After the flight beetle did not enter the soil through the emergence hole. They dug into soil and the entry point

Plate III. 'Emergence hole' in the soil made by the beetles of L. coneophora.



could not be easily detected except for the loose soil particles at the site.

Adult feeding.

The beetles were not seen congregating on any plant species in the infested locality or feeding on any plant parts. Fifty beetles were dissected and examination of their gut content did not show any food material. Leaves and roots of coconut palm, banana, caoao, crotalaria, elephant foot yam, cassava, colocasia, eupatorium, pigeon pea, drumstick plant, rose and different grasses were provided in the laboratory to the adults of L. coneophora for feeding. But there was no indication of feeding on the materials provided.

3.1.6 Detailed diagnostic features of third instar grub.

For the purpose of distinguishing grubs of L. coneophora from those of related species, detailed morphological characters of the third instar grub were studied. The diagnostic features noted are detailed below.

Cranium (Plate IV a).

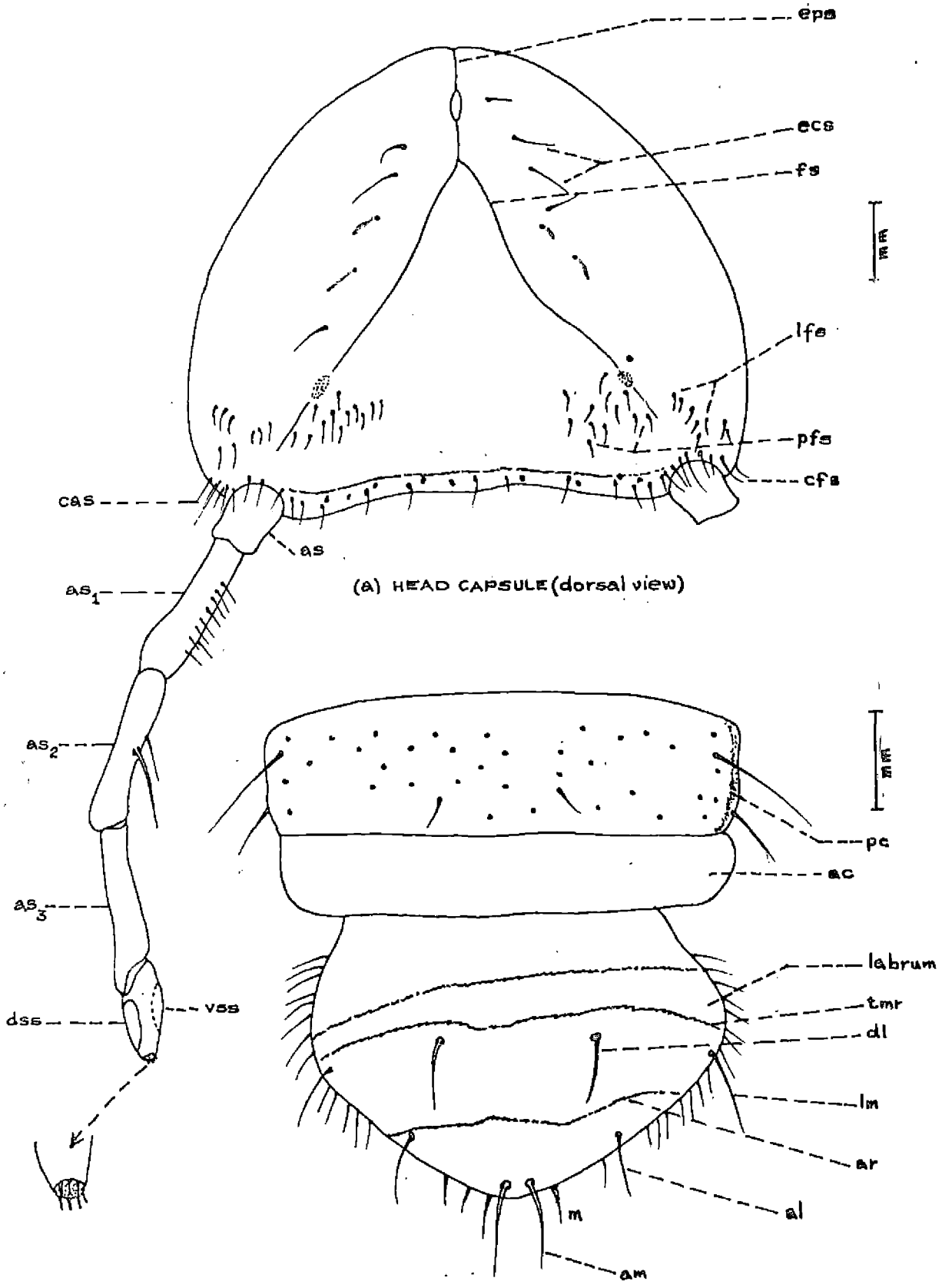
Antero-frontal setae (afs) 20-24, exterio-frontal setae (pfs) 11-16 on each side in a cluster set in an irregular patch; circum-antennal setae (cas) 11-13 unequal in length; epicranial setae (ecs) 6 obliquely

Plate IV. External morphology of the third instar grub of *L. coneophora*.

a) head capsule and antenna

b) clypeus and labrum

PLATE. IV.



(a) HEAD CAPSULE (dorsal view)

(b) CLYPEUS AND LABRUM

set on either side of epicranial and frontal sutures; epicranial suture (eps) less than one third the frontal suture; frontal suture (fs) distinct, extending up to and near the base of antennal socket (as) with a granular patch towards distal end; clypeo-frontal suture (cfs) distinct, ridge-like; lateral frontal setae (lfs) 8, long and uniformly set on each dorso-lateral side of frontal suture anterior to circum-antennal setae.

Antenna (Plate IV a).

First antennal segmental setae (as 1) 9-11; second antennal segmental setae (as 2) 2; one of them long and prominent set at about middle of the segment.

Clypeus (Plate IV b).

Post-clypeus (po) trapezoidal, bearing two prominent, one dorso-lateral and one lateral setae on each side, rugoso-punctate, anteclypeus (ac) less sclerotised, nongranular and nonsetaceous.

Labrum (Plate IV b).

Transverse median ridge (tmr) prominent; anterior ridge (ar) distinct; setae: 1 pair each of anterior median (am) anterior lateral (al) lateral median (lm) and dorso-lateral (dl).

Epipharynx (Plate V a).

Rounded even margin, acroparia (acrp) with 25-45 long pointed setae; plegmatia (plg) 14-18; proplegmatia minutely rugouse; acanthoparia (acp) 22-27; heli (h) in three rows 21-25; chaetoparia (chp) many, distributed all over, more prominent and clustered towards the pedium (p); zygum absent; epizygum poorly developed; dexiotorma (dxt) strong, well sclerotized; pternotorma (ptt) well developed, separate or fused with laeotorma; laeotorma (laeo) dark, strong; crepis (crp) thin, nearly U-shaped.

Mandible (Plate V b).

Left: molar region (mr), dorsomolar area (ma) dorso-exterior region (dex) and calx (clx) well developed; dorso-molar setae (dms) 7-9, postero-lateral dorsal molar setae (plm) 10-12, and about the same number on the ventral side; scorbis (scr) setae 8-10, dorso-lateral setae (dls) 5-9, scissorial part (sci) wavy.

Right: dorsomolar setae (dms) 10-12; dorsal and ventral postero-lateral (plm) setae 6-7.

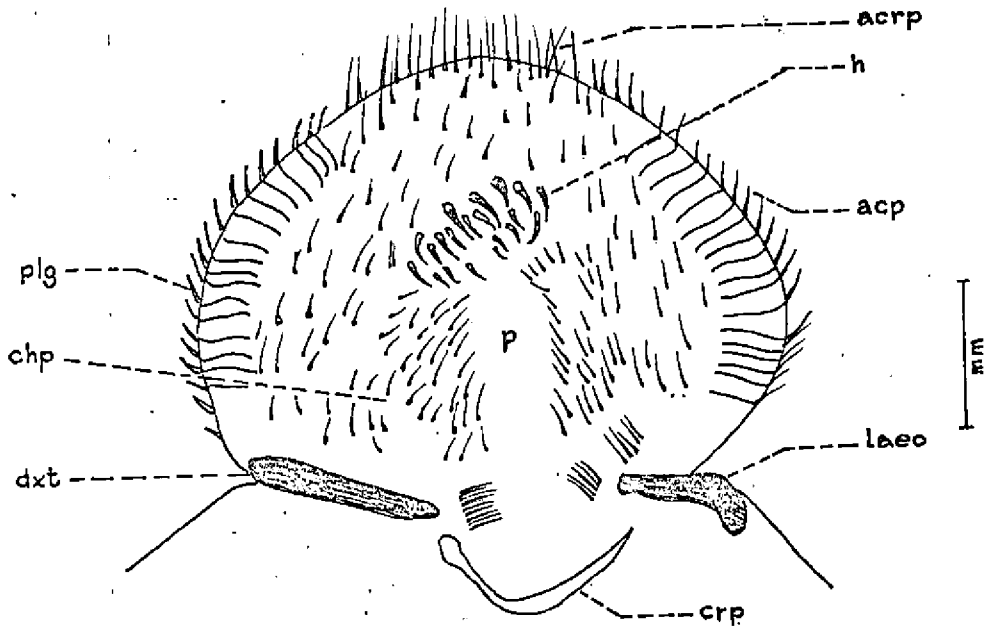
Maxilla (Plate VI a).

Cardo (c) setose; stipes (st) elongate; stridulatory teeth (stt) 16-18, conical, arranged in a single line from the base of the stipes to three-fourths the length distally; unci of galea (gu) and lacinia together (lu) 6-7.

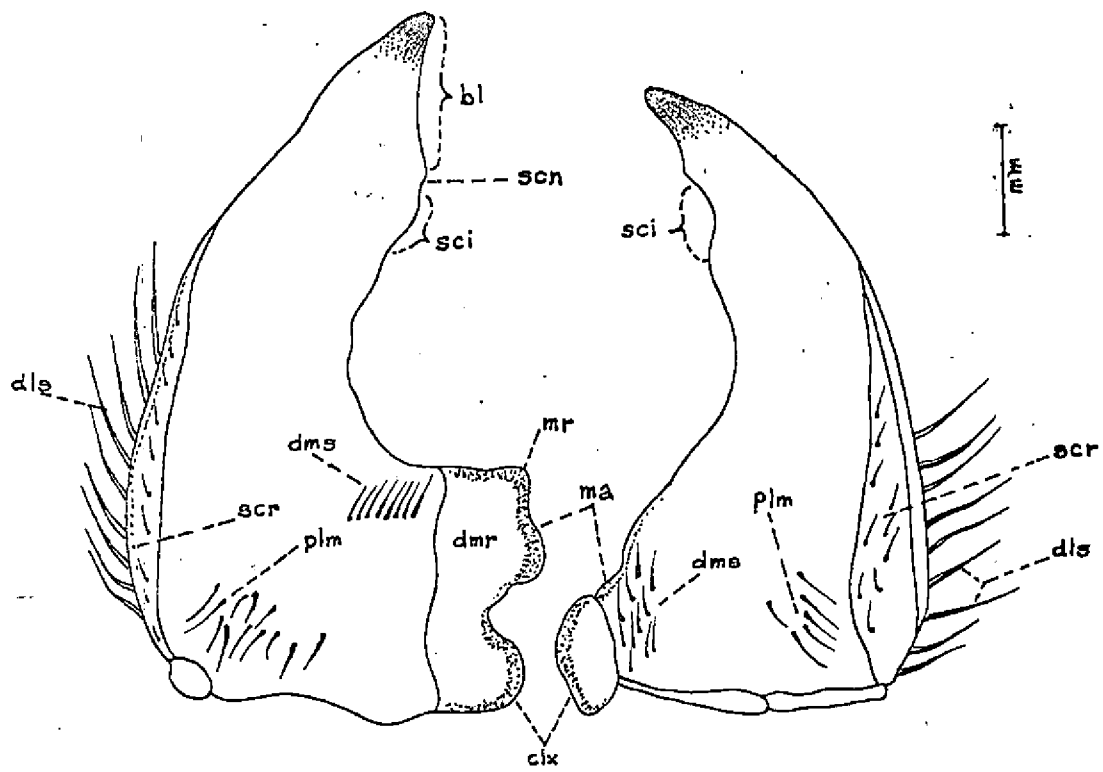
Plate V. External morphology of the third instar grub of L. coneophora (continuation).

a) epipharynx

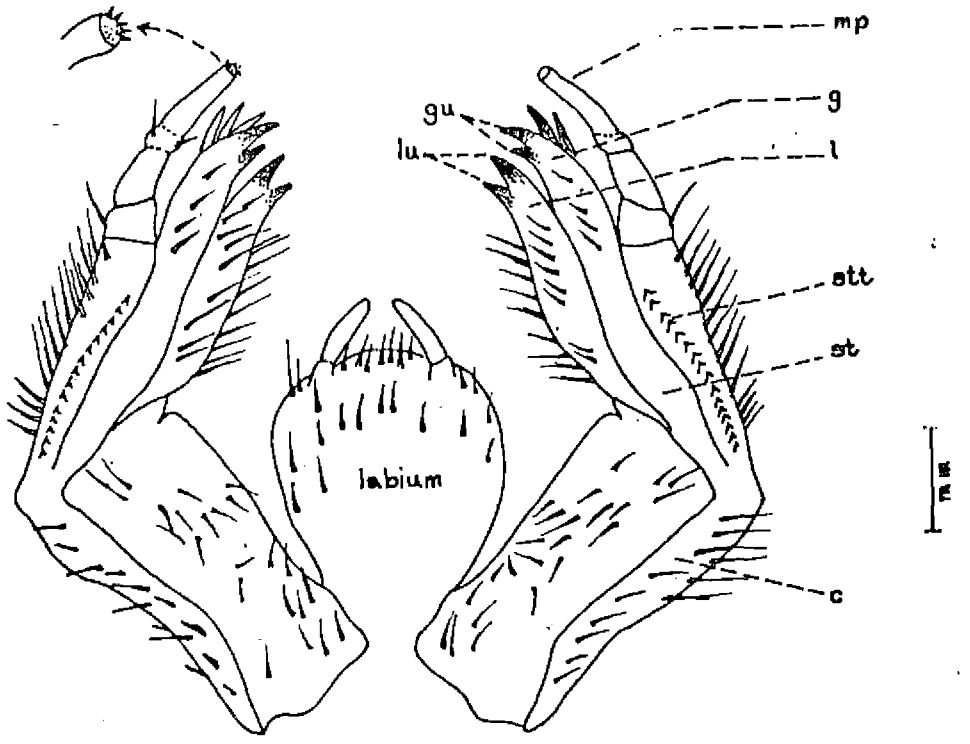
b) mandibles - dorsal view



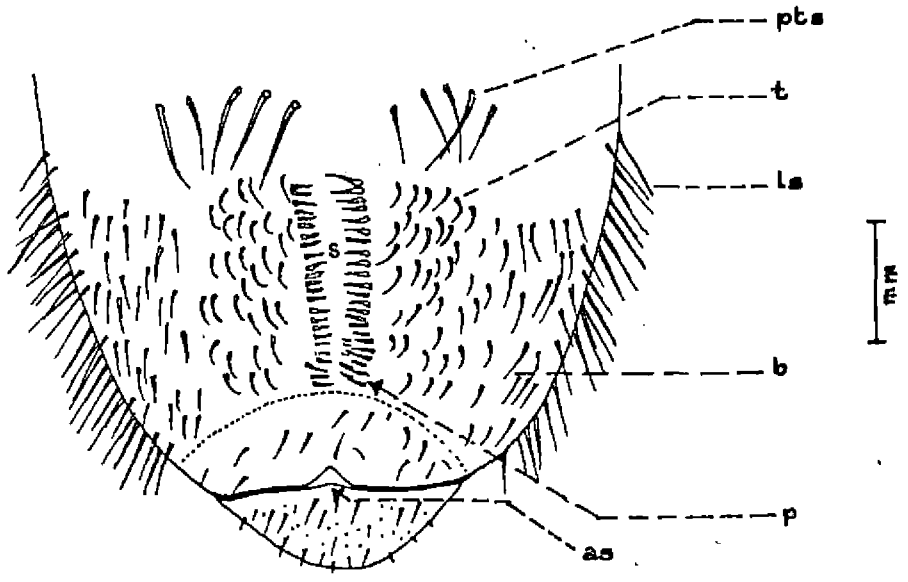
(a). EPIPHARYNX



(b). MANDIBLES (dorsal view)



(a). MAXILLAE AND LABIUM



(b). RASTER

Raster (Plate VI b).

Septula (s) long, narrow, nearly closed by pali; pali (p) 22-28; tegellum (t) 55-60, peg like short and stout appearing in nearly linear rows from the anterior to the posterior end; pretegellar setae (pts) 4-5 on each side, prominent, very long and slender; barbula (b) 100 or more; lateral setae (ls) 30-40; anal opening angulate.

Key to the different species of Leucopholis found in South India, based on larval characters.

1 Antero-frontal setae 14-16 arranged
in a single transverse line;
acanthoparia 15-17; right dorsomolar
setae 18-20.....L. burmeisteri Blanch.

- Antero-frontal setae 20-25, arranged
in a transverse line or in irregular
rows; acanthoparia 20-27; right
dorsomolar setae 10-12.....2

2 Epicranial setae 6; circumantennal
setae 11-13; proplegmatia rugose;
acanthoparia 22-27; epizygum poorly
developed.....L. coneophora Burm.

- Epicranial setae 4; circumantennal
setae 25-28; proplegmatia absent;
acanthoparia 20-22; epizygum absent...L. lepidophora Brenske

3.2 Effect of different hosts on the biology of L. coneophora

3.2.1 Effect on duration of life stages.

Data relating to the larval and pupal duration of L. coneophora reared on different host plants are presented in Table 1 and Fig. 2. The duration of the first instar grubs reared on different hosts did not vary significantly, though the variation ranged from 38.2 to 42 days in the case of males and 40.2 to 41.6 days in the case of females.

The shortest development period of the second instar grub of the males was observed on cassava (48.8 days) and it was closely followed by the duration on coconut (51.6 days) the difference between the two being statistically insignificant. The duration of development on cacao was significantly higher than that of cassava but the former was on par with that of cocconut. The maximum duration was observed on crotalaria and it was significantly higher than the duration observed on other host plants.

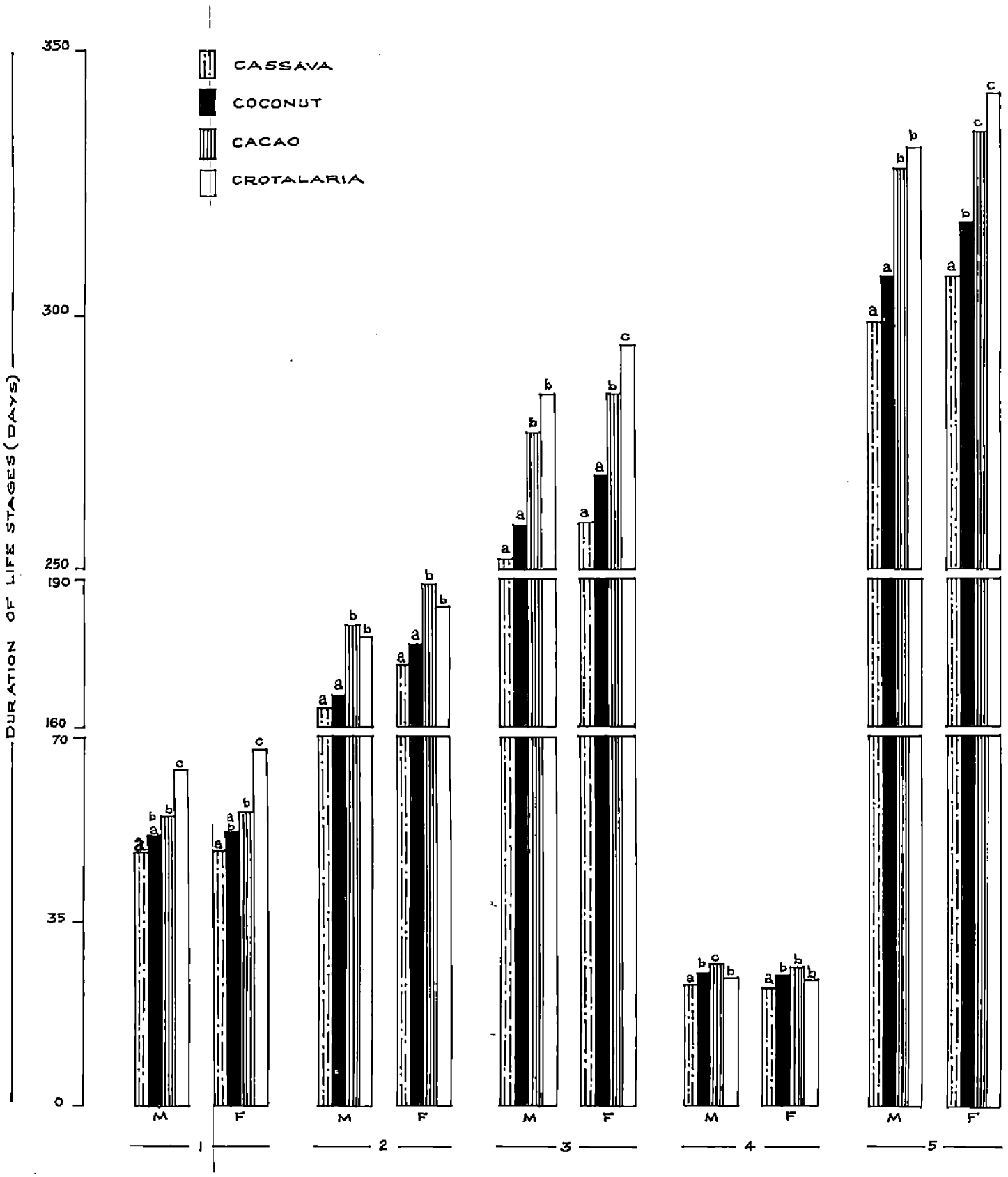
With regard to the duration of development of the female insects also cassava and cooonut were on par and the latter was on par with cacao. The duration of development on crotalaria was the maximum and it was significantly higher than those on other host plants.

Table 1. Effect of different host plants on the biology of L. coneophora.

host plants	mean larval duration (days)				mean pupal duration (days)	mean duration from egg to adult (days)
	first instar	second instar	third instar	total		
Male						
Cassava	38.2 (35 - 42)	48.8[a] (44 - 54)	166.0[a] (151 - 177)	253.0[a] (242 - 262)	23.3[a] (22 - 26)	299.3[a] (290 - 309)
Coconut	40.3 (34 - 46)	51.6[ab] (45 - 60)	168.1[a] (155 - 173)	260.0[a] (249 - 269)	25.3[b] (23 - 29)	308.3[a] (295 - 317)
Cacao	40.5 (37 - 47)	55.7[b] (44 - 71)	181.9[b] (170 - 187)	278.1[b] (253 - 294)	26.8[c] (24 - 29)	327.9[b] (302 - 346)
Crotalaria	42.0 (36 - 49)	63.4[c] (53 - 71)	179.7[b] (161 - 201)	285.1[b] (265 - 315)	24.7[b] (23 - 26)	332.8[b] (313 - 362)
CD	NS	6.19	8.61	10.10	1.45	10.09
Female						
Cassava	40.2 (36 - 45)	48.8[a] (43 - 55)	172.8[a] (158 - 183)	261.8[a] (250 - 273)	22.9[a] (21 - 24)	307.7[a] (297 - 320)
Coconut	40.9 (38 - 51)	51.6[ab] (40 - 57)	177.5[a] (164 - 189)	270.0[a] (257 - 281)	25.7[b] (23 - 29)	318.7[b] (304 - 333)
Cacao	41.6 (35 - 47)	55.5[b] (43 - 71)	188.7[b] (181 - 199)	285.8[b] (269 - 298)	26.1[b] (24 - 29)	334.9[c] (316 - 348)
Crotalaria	41.4 (35 - 48)	67.7[c] (59 - 76)	185.1[b] (170 - 201)	294.2[c] (281 - 304)	25.2[b] (23 - 28)	342.4[c] (330 - 352)
CD	NS	5.92	7.45	7.21	1.89	7.83

Notations with different letters indicate significant difference at 1% level.
Figures in parentheses show the range. NS = Not significant.

FIG. 2.


CASSAVA
COCONUT
CACAO
CROTALARIA
DURATION OF LIFE STAGES (DAYS)
350
300
250
190
160
70
35
0
M
F
1
2
3
4
5

The development of the third instar grub also was significantly influenced by the host plants. The duration of males on cassava (166 days) was the minimum and it was closely followed by the duration on coconut (168.1 days) the difference between the two being statistically insignificant. The development on cacao (181.9 days) was on par with that of crotalaria (179.7 days) and these were significantly longer than the durations on coconut and cassava. With reference to the female also the duration on cassava and coconut was found to be on par and significantly shorter than the duration on cacao and crotalaria the latter two also being on par.

Considering the total duration of grubs also cassava and coconut could be ranked on par, the duration being 253 and 260 days, respectively, in the case of males and 261.8 and 270.0 days, respectively, in the case of females. In the case of males the duration of development on cacao (278.1 days) and crotalaria (285.1 days) were also on par and they were significantly longer than those on cassava and coconut. In the case of the females the total durations in crotalaria (294.2 days) were significantly higher than that on cacao (285.8 days).

The pupal duration of the insects reared on cassava was the shortest (23.3 days) and those of coconut and crotalaria were on par with that on cassava and significantly shorter than that on cacao. In the case of females also the pupal duration was shortest on cassava (22.9 days), while the durations on the coconut, cacao and crotalaria were on par and significantly longer than that of cassava.

With reference to the total life period from egg to adult, cassava and coconut were found to be very suitable for the pest, there being no significant difference between the duration of males on these hosts (299.3 and 308.3 days, respectively). But in the case of females, cassava was found to be significantly superior to coconut having a shorter duration. In the case of males and females the total durations on cacao and crotalaria were found to be on par and significantly longer than those on the other two hosts.

3.2.2 Effect of different hosts on the body size of the life stages.

Data relating to the body size of grubs reared on different host plants are presented in Table 2.

Body length of the full grown grubs reared from first instar on cassava was the maximum (49.3 mm for males and 56.8 mm for females) and it was closely followed

Table 2. Effect of different host plants on the size and weight of third instar grubs of L. coneophora.

host plants	length (mm)	width (mm)	weight (g)
	Male		
Cassava	49.3[a] (43 - 53)	14.1[a] (12 - 16)	3.39 (2.87 - 4.11)
Coconut	48.8[ab] (42 - 52)	13.9[a] (13 - 15)	3.42 (2.67 - 4.98)
Cacao	46.8[b] (42 - 50)	12.8[b] (12 - 14)	3.10 (2.40 - 3.38)
Crotalaria	44.1[c] (42 - 47)	13.4[b] (12 - 15)	2.88 (2.50 - 3.52)
CD	2.333	0.846	NS
	Female		
Cassava	56.8[a] (55 - 58)	15.9[ab] (15 - 18)	5.82[a] (5.03 - 6.29)
Coconut	56.3[a] (52 - 60)	16.3[a] (15 - 17)	5.68[a] (4.78 - 6.65)
Cacao	53.9[b] (52 - 55)	15.5[b] (15 - 16)	4.94[b] (4.18 - 5.29)
Crotalaria	50.3[c] (48 - 53)	15.2[b] (14 - 16)	4.40[c] (2.96 - 5.07)
CD	1.570	0.727	0.512

Notations with different letters indicate significant differences at 1% level for length and weight and at 5% level for width.

NS = Not significant

Figures in parentheses give the range.

by those reared on coconut, there being no significant difference between the two. In the case of males reared on coconut (48.8 mm) and cacao (46.8 mm) the mean length did not vary significantly, while those reared on crotalaria were the shortest and significantly different from those reared on all the other hosts. In the case of females the length of grubs reared on cacao and crotalaria were significantly lower than the length of grubs reared on coconut.

The mean body width of full grown grubs of the males reared on cassava was the highest (14.1 mm) and it was closely followed by the width of grubs reared on coconut (13.9 mm) the difference between the two being statistically insignificant. In the case of females the body width of grubs reared on coconut and cassava (16.3 and 15.9 mm, respectively) were on par and significantly higher than those obtained from the remaining treatments. Minimum body width was observed for grubs reared on cacao and it was preceded by those reared on crotalaria in the case of males and crotalaria was preceded by cacao in the case of female insects, the difference between them being statistically insignificant.

The body weight of full grown grubs of males reared on different hosts did not differ significantly though the variation ranged from 2.88 g to 3.42 g.

Body weight of female grubs reared on cassava was the highest (5.82 g) and it was closely followed by grubs obtained from coconut (5.68 g). The difference between the two was statistically insignificant. Grubs obtained from cacao weighed 4.94 g, and was significantly less than the weight of grubs on coconut and cassava and more than the weight of grubs on crotalaria (4.4 g). Minimum weight was obtained for grubs reared on crotalaria and the same was significantly less than those reared on other crops.

Data on the size of pupae obtained from insects reared on different host plants are given in Table 3.

The mean lengths of the pupae of males reared on cassava and coconut (31.3 mm) was higher and on par and these differed significantly from the length of pupae reared on cacao and crotalaria the latter two being on par. The body length of pupae reared on cacao and crotalaria did not differ significantly. Maximum pupal length in the case of females was recorded on cassava followed by coconut (36.0 mm and 35.5 mm, respectively) and they were on par between themselves. Body length of pupa reared on crotalaria (30.4 mm) was the least. The body length of pupa obtained from cacao differed significantly from the remaining hosts and was lesser than that on coconut and more than that on crotalaria.

Table 3. Effect of different host plants on the size and weight of pupae of L. coneophora.

host plants	length (mm)	width (mm)	weight (g)
Male			
Cassava	31.3^{a} (29 - 35)	15.0^{a} (14 - 17)	2.75^{a} (2.51 - 3.03)
Coconut	31.3^{a} (30 - 34)	15.0^{a} (14 - 17)	2.35^{b} (2.06 - 2.63)
Cacao	28.7^{b} (26 - 35)	13.7^{b} (12 - 15)	2.23^{b} (1.90 - 2.50)
Crotalaria	28.1^{b} (25 - 32)	13.2^{b} (12 - 15)	2.35^{b} (1.98 - 2.98)
CD	2.113	0.915	0.263
Female			
Cassava	36.0^{a} (35 - 38)	17.0^{a} (15 - 18)	4.56^{a} (4.02 - 5.92)
Coconut	35.5^{a} (34 - 38)	16.8^{ab} (16 - 18)	4.28^{a} (3.85 - 4.63)
Cacao	33.2^{b} (29 - 26)	15.7^{bc} (14 - 18)	3.36^{b} (2.48 - 4.66)
Crotalaria	30.4^{c} (27 - 35)	15.2^{c} (13 - 17)	2.77^{c} (2.10 - 4.00)
CD	1.806	1.114	0.513

Notations with different letters indicate significant differences at 1% level.

Figures in parentheses show the range.

With reference to the mean body width of pupae cassava and coconut were found to be the favourable hosts the measurements being on par and high in the case of male and female. In the case of males the body widths of pupae from cacao and crotalaria were on par and they were significantly lower than those obtained from coconut and cassava. In the case of females the body width of pupae reared on crotalaria was the least and it was preceded by those obtained from cacao the difference between the two being statistically insignificant. Cacao and coconut were also seen on par.

Maximum pupal weight was obtained for insects reared on cassava. In the case of males weight of pupae reared on cassava was significantly superior to those reared on the remaining hosts. Minimum body weight of pupae of males was obtained for insects from cacao, and it was on par with the body weight of pupae obtained from coconut and crotalaria. In the case of females, weight of pupae from coconut and cassava did not differ significantly. Minimum pupal weight (2.77 g) recorded for pupae from crotalaria was significantly lower to that of the pupae from remaining hosts. The mean weight of pupae obtained from cacao was higher than those obtained from crotalaria and lower than those from coconut and cassava.

The data on body size of adults obtained from grubs reared on different hosts are given in Table 4. Body length of males and females obtained from coconut and cassava were on par and significantly higher than those obtained from the other hosts. Body length of adults obtained from cacao and crotalaria were on par and less than those obtained from cassava and coconut in the case of males. In the case of females minimum body length was for adults reared on crotalaria.

The body width of the adult males reared from different hosts did not vary significantly. Regarding females the maximum width was recorded for insects reared on coconut (16.9 mm) and it was closely followed by those reared on cassava (16.1 mm) the difference between the two being statistically insignificant. The lowest width was noted for the insects reared on cacao (14.3 mm) and it was preceded by those reared on crotalaria (15.6 mm) the difference between the two being statistically significant. The body weight of adults obtained from cassava was maximum for both sexes (1.79 g and 3.24 g for male and female, respectively) and these were on par with those reared from coconut (1.69 g and 3.16 g for male and female on coconut). In the case of males, minimum weight was for insects obtained from crotalaria and the same significantly differed from the insects

Table 4. Effect of different host plants on the size and weight of adults of L. coneophora.

host plants	length (mm)	width (mm)	weight (g)
	Male		
Cassava	26.8[a] (24 - 30)	13.5 (12 - 15)	1.79[a] (1.61 - 2.02)
Coconut	26.8[a] (26 - 28)	13.6 (12 - 16)	1.69[ab] (1.34 - 2.10)
Cacao	25.2[b] (22 - 29)	13.1 (12 - 16)	1.52[b] (1.03 - 1.80)
Crotalaria	23.8[b] (22 - 26)	12.7 (11 - 16)	1.21[c] (1.00 - 1.81)
CD	1.485	NS	0.208
	Female		
Cassava	30.8[a] (29 - 32)	16.1[ab] (15 - 17)	3.24[a] (2.80 - 3.46)
Coconut	30.9[a] (27 - 32)	16.9[a] (13 - 18)	3.16[a] (2.72 - 4.21)
Cacao	29.0[b] (27 - 32)	14.3[c] (13 - 16)	2.48[b] (1.82 - 2.81)
Crotalaria	27.5[c] (25 - 30)	15.6[b] (15 - 17)	2.20[b] (1.98 - 2.76)
CD	1.474	1.051	0.341

Notations with different letters indicate significant difference at 1% level.

NS = Not significant

Figures in parentheses show the range.

reared on other hosts. Body weight of males reared on cacao was slightly less than the weight of adults reared on cocoonut, but they did not differ significantly. In the case of females the minimum body weight was for adults reared on crotalaria (2.20 g) and that did not differ significantly from the weight of insects reared on cacao (2.48 g).

3.2.3 Effect of different hosts on the survival of immature stages, adult longevity, preoviposition period and fecundity.

The data relating to the survival of the different life stages of L. coneophora reared on different hosts (Table 5; Fig. 3) when subjected to χ^2 test of independence revealed that there were no significant variations in the test insects surviving up to third instar stage of the pest. The third instar grubs surviving to pupal instars varied significantly with reference to different hosts. The maximum number was obtained from cassava and it was followed by cocoonut, cacao and crotalaria. The adult emergence was also noted to be the maximum in cassava (69) and it was followed by the number obtained from cocoonut (63) cacao (42) and crotalaria (40). The gradual increase in the χ^2 values from the second instar to the adult stages indicated increasing influence of the hosts in later instars of the insect.

Table 5. Effect of different host plants on the survival of the immature stages of L. coneophora and the longevity, pre-oviposition period and fecundity of adults.

host plants	No. of first instar grub observed	first instar grub surviving till attaining: second instar stage	third instar stage	pupal stage	adult stage		adult longevity (days): mean	range	mean pre-oviposition period (days)	mean No. of eggs/ female	mean per cent of eggs hatched
Cassava	200	150	128	85	69	M	44.7^{a}	(36 - 54)			
						F	48.7^{d}	(45 - 53)	34.0^{a}	19.4^{a}	96.8^{a}
Coconut	200	140	126	72	63	M	42.3^{ab}	(36 - 50)			
						F	42.6^{e}	(37 - 50)	34.8^{a}	18.5^{a}	95.0^{a}
Cacao	200	140	124	62	42	M	38.7^{bc}	(31 - 46)			
						F	34.5^{f}	(30 - 39)	30.9^{b}	8.9^{b}	58.2^{b}
Crotalaria	200	150	124	67	40	M	37.8^{c}	(31 - 43)			
						F	33.2^{f}	(30 - 37)	30.5^{b}	7.2^{b}	65.5^{b}
	χ^2	2.51	4.91	8.35*	17.13**						
					CD	M	4.42				
					CD	F	2.89		2.15	2.52	13.24

M = Male F = Female

Notations with different letters indicate significant differences at 1% level for males and at 5% level for females.

*Significant at 5% level **Significant at 1% level.

Fig. 3. Effect of different host plants on the survival of the immature stages of L. coneophora.

Fig. 4. The longevity, preoviposition period and fecundity of L. coneophora reared on different host plants.

FIG. 3.

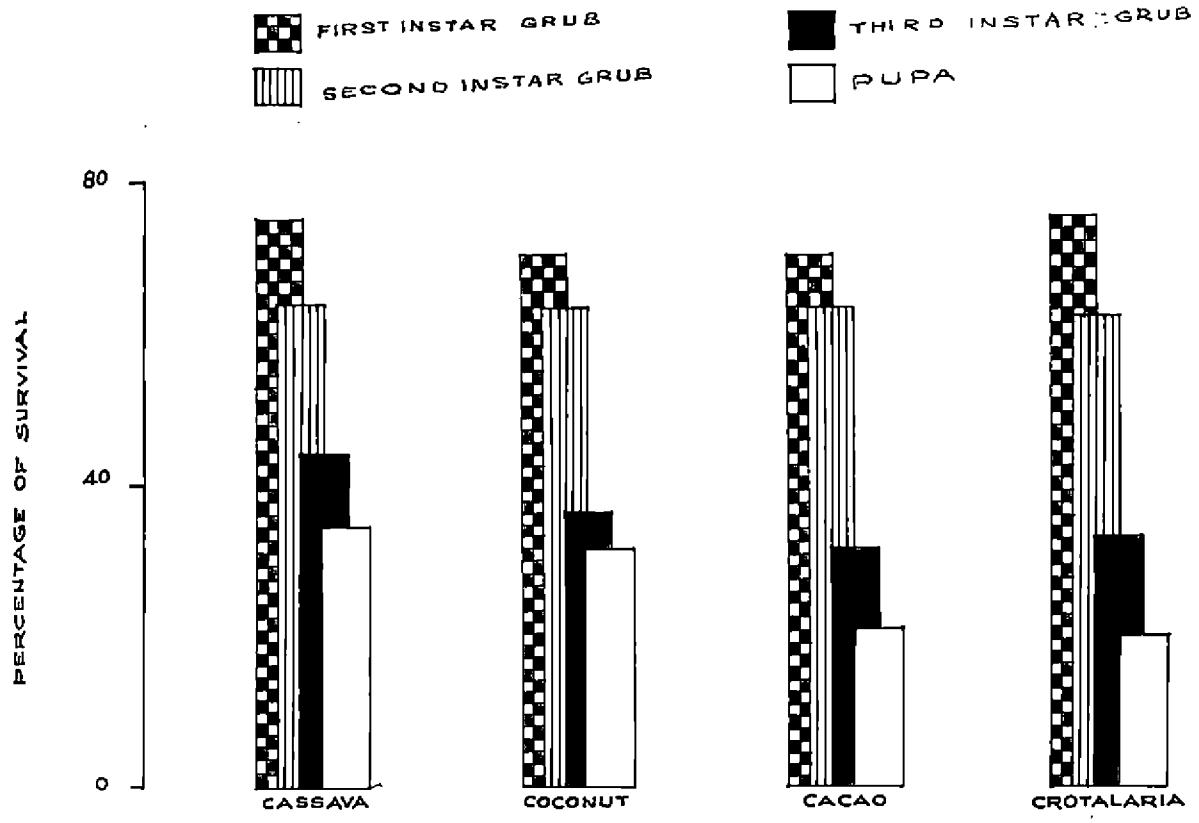
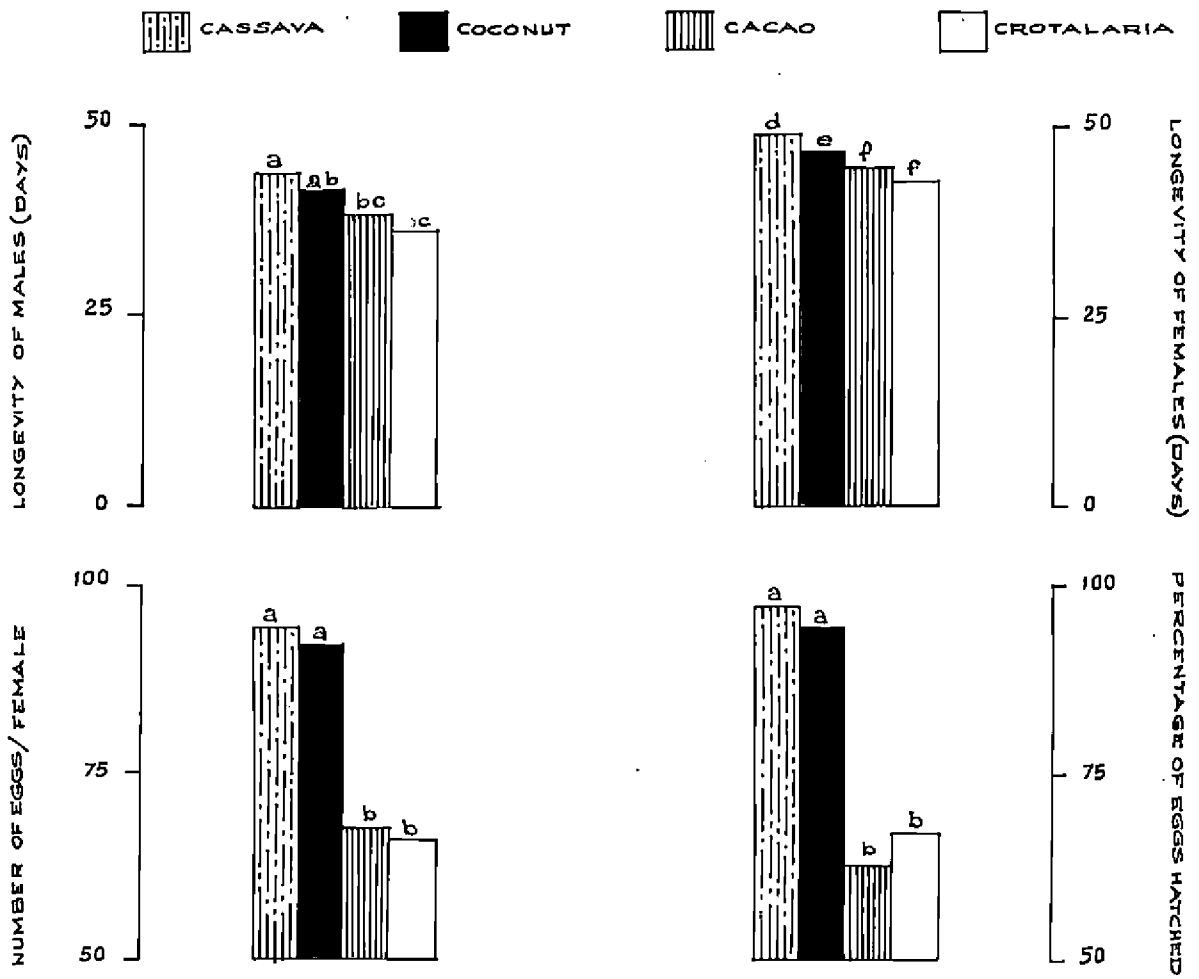

FIRST INSTAR GRUB
SECOND INSTAR GRUB
THIRD INSTAR GRUB
PUPA
PERCENTAGE OF SURVIVAL
80
40
0
CASSAVA
COCONUT
CACAO
CROTALARIA

FIG. 4


CASSAVA
COCONUT
CACAO
CROTALARIA
LONGEVITY OF MALES (DAYS)
50
25
0
a
ab
bc
c
d
e
f
f
LONGEVITY OF FEMALES (DAYS)
NUMBER OF EGGS/FEMALE
100
75
50
a
a
b
b
a
a
b
b
PERCENTAGE OF EGGS HATCHED

Data relating to adult longevity, preoviposition period and fecundity are given in Table 5 and Fig. 4.

In the case of adult males longevity recorded for insects reared on cassava was maximum (44.7 days) followed by those reared on coconut (42.3 days) the difference being insignificant. Males obtained from cacao had lower longevity, but did not differ significantly from the longevity of the males obtained from coconut. Minimum longevity was for adults obtained from crotalaria (37.8 days) and it was also on par with the longevity of adults obtained from cacao. In the case of females, maximum longevity was recorded for adults reared on cassava (48.7 days), which was significantly different from the longevity of adults obtained from other host plants. Minimum longevity was recorded for the females reared on crotalaria (33.2 days), which was on par with the longevity of those reared from cacao (34.5 days). Longevity of females reared ~~out~~ from coconut (42.6 days) was significantly lower than the longevity of adults obtained from cassava and higher than the longevity of insects reared on cacao and crotalaria.

Preoviposition periods of females reared ~~out~~ from cassava and coconut (34.0 and 34.8 days, respectively) were on par and differed significantly from those reared

on cacao and crotalaria (30.9 and 30.5 days, respectively). The difference between the latter two also was not significant. Similarly, the mean number of eggs laid per female did not differ significantly between females reared out from cassava and coconut (19.4 and 18.5 eggs per female, respectively). Minimum number of eggs was recorded for females reared out from crotalaria (7.2 per female) and this was on par with the number of eggs obtained from adults reared on cacao (8.9 per female).

Hatching percentage of eggs was also influenced by different host plants of the grubs. Maximum number of eggs laid by females reared out from cassava hatched and it was closely followed by the hatching percentage of the eggs laid by adults obtained from coconut (96.8 and 95.0 per cent, respectively) there being no significant difference between the two. Hatching was considerably low for eggs laid by females obtained from cacao (58.2 per cent) and crotalaria (65.5 per cent) and the difference between them was insignificant.

3.3 Nature of injury caused by grubs of *L. coneophora* to different plant hosts

3.3.1 Cassava (*Manihot esculenta* Cranz.)

Out of 50 plants exposed to the grub, seven did not sprout, 13 died after sprouting within 30 days of

planting, while 30 survived with retarded growth. The sprouting in control plants was normal and all the plants got established. Seven plants which did not sprout were seen attacked by grubs and the rind of the sett below the ground level was completely eaten away and even the woody portion was partially gnawed out. The grubs were seen very close to the stem. Thirteen plants sprouted normally and the leaves turned yellow and subsequently got dried up. The rind of the underground portion of these setts was also seen eaten up and no healthy shoots could be seen at the time of examination. The setts could have been attacked by the grubs subsequent to sprouting. Thirty plants which survived till the end had tapering stem and their leaves were reduced in size and pale green in colour. When taken out the rind of the underground portion of the setts was seen partially fed and the roots were severed at different lengths away from the stem (Plate VII a). The plants which were not irrigated at later stages got dried up at the end of thirty days.

The injury done by different levels of grub population introduced in four-month-old plants and as observed at harvest are presented in Table 6, Fig. 5 and Plate VII b. It may be seen that height of plants, exposed to grub population ranging from one to five number per plant,

Table 6. Extent of damage done to cassava (Manihot esculenta) by different levels of grub population of L. consephora.

	No. of grubs/plant				
	0	1	3	5	CD
Height (cm)	263.29[a]	206.00[b]	201.47[bc]	186.60[c]	17.42
Girth (cm)	4.20[a]	3.97[b]	3.80[c]	3.51[d]	0.126
No. of leaves emerging after introduction of grubs.	70.20[a]	54.46[b]	52.93[b]	49.00[b]	9.21
Weight of top growth (g)	1388.33[a]	1031.80[b]	924.53[c]	873.93[c]	87.89
Weight of roots other than tubers (g)	202.89[a]	184.87[ab]	116.68[b]	77.26[b]	76.29
Weight of damaged tubers (g)	0.00[a]	603.93[b]	759.47[b]	817.80[b]	254.99
Weight of undamaged tubers (g)	2860.80[a]	2215.40[b]	2035.33[b]	1221.13[c]	343.00
Weight of underground growth (g)	3063.67[a]	2423.03[b]	2151.00[b]	1334.98[c]	388.69

Notations with different letters indicate significant difference at 1% level.

FIG. 5.

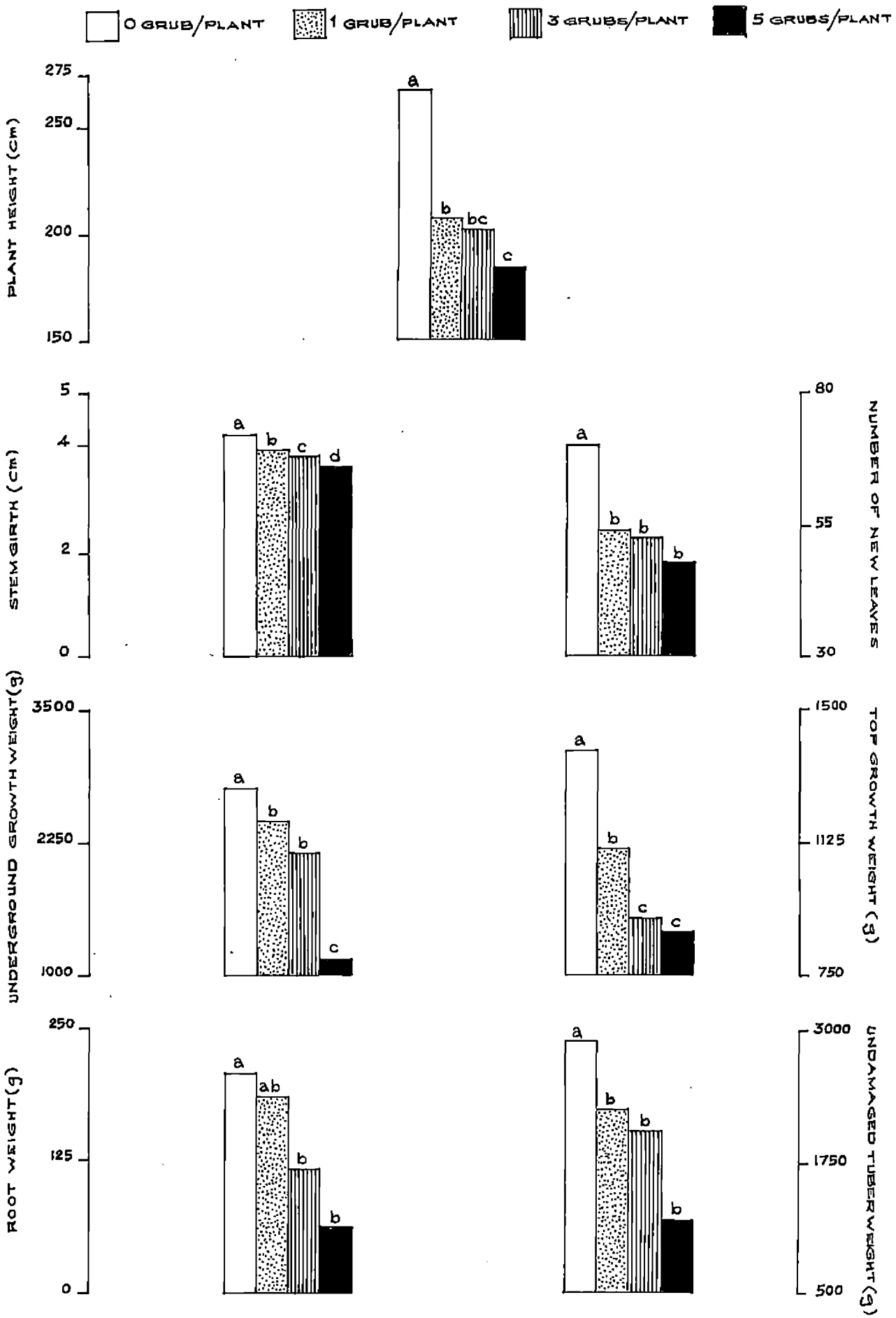

0 GRUB/PLANT
1 GRUB/PLANT
3 GRUBS/PLANT
5 GRUBS/PLANT
PLANT HEIGHT (cm)
275
250
200
150
a
b
bc
c
STEM GIRTH (cm)
5
4
2
0
a
b
c
d
a
b
b
b
NUMBER OF NEW LEAVES
80
55
30
UNDERGROUND GROWTH WEIGHT (g)
3500
2250
1000
a
b
b
c
a
b
c
c
TOP GROWTH WEIGHT (g)
1500
1125
750
ROOT WEIGHT (g)
250
125
0
a
ab
b
b
a
b
b
b
UNDAMAGED TUBER WEIGHT (g)
3000
1750
500

Plate VII. Nature of damage on cassava (*Manihot esculenta*) caused by *L. coneophora*.

a) seedling - damaged and healthy

b) damaged tubers

a

ranged from 206 to 186.6 cm as against 263.29 cm in control plants. The population levels of one and three grubs per plant were on par while the latter was on par with the highest population level of five grubs per plant. With reference to the girth of plants also the infestation brought significant reduction when compared to control. The mean girth of plants exposed to the pest at levels of one, three and five grubs per plant were 3.97, 3.8 and 3.51 cm, respectively. These values were significantly different from one another. With reference to the number of leaves which emerged after the release of grubs there was significant difference between the control and treatments while the treatments were on par. The weight of top growth of the plants also varied significantly between the treatments and control. The reduction caused by three and five grubs per plant (924.53 and 873.93 g, respectively) was on par and was significantly higher than that caused by one grub per plant (1031.8 g). The weight of roots (excluding tubers) in plant exposed to three and five grubs were 116.68 and 57.26 g, respectively, and these were on par. The root weight in plants exposed to one grub was on par with that of control. Weight of damaged tubers in plants exposed to the pest at the rate of one, three and five grubs per plant viz. 603.93,

759.47 and 817.80 g, respectively, were on par and no damage was noticed in control plants. The weight of underground growth (root and tubers) also varied significantly between control and treatments. The weight in plants exposed to one and three grubs (2423.08 and 2151.00 g, respectively) did not vary significantly while the weight of plants exposed to five grubs was significantly low (1384.98 g). The weight of underground growth (3063.67 g) was significantly higher in control.

Qualitative changes in tubers partly damaged by the feeding of the grubs of L. coneophora.

Results presented in Table 7 showed that the tubers collected from the control plants and the undamaged tubers obtained from plants infested by the root grubs did not differ significantly with reference to the starch and hydrocyanic acid (HCN) contents as well as amylose amylopectin ratio. But the starch content of the damaged tubers was significantly lower than that of control, the percentages being 53.25 and 67.97, respectively. Amylose and amylopectin ratio in the tubers collected from the control plant was 24.37 : 75.63 whereas the same was higher in tubers damaged by the grubs, the ratio being 16.52 : 83.45. The HCN content of the damaged tubers was significantly lower the quantities being 25.19 and

Table 7. Effect of feeding by grubs of L. conoephora on the starch, amylose, amylopectin and HCN contents of cassava tubers.

	mean values of			CD
	control plant	undamaged tuber of infested plant	damaged tuber of infested plant	
Starch %	67.97[a] (62.6 - 76.2)	70.22[a] (62.0 - 76.2)	53.25[b] (50.1 - 58.1)	4.152
Amylose %	24.37[a] (23.2 - 26.0)	23.76[a] (22.1 - 26.2)	16.52[b] (14.8 - 19.7)	1.250
Amylopectin %	75.63[a] (74.0 - 77.8)	76.34[a] (73.8 - 77.9)	83.45[b] (80.3 - 85.2)	1.267
HCN µg/1 g	25.19[a] (16.2 - 40.2)	23.38[a] (18.0 - 33.3)	11.17[b] (5.7 - 15.7)	5.474

Notations with different letters indicate significant difference at 1% level. Figures in parentheses show the range.

11.17 µg/g in control and treatment, respectively.

The cooking quality of damaged tubers was also seen badly affected. These tubers were poorly cooked, less starchy, non-mealy, less tasty, hard and slightly yellowish in colour. The taste panel found them less acceptable for consumption.

3.3.2 Cacao (Theobroma cacao Linn.).

The damage caused by different levels of grub population on five-month-old plants and as observed at 45 days after the introduction of the grub are presented in Table 8 and Fig. 6. The damage caused even by the population level of one grub per plant was highly significant when compared to control. The height of the plant was reduced from 52.13 to 44.53 cm, tap root length from 25.27 cm to 17.4 cm, weight of top growth from 19.88 to 13.95 g and weight of underground growth from 9.59 to 6.33 g. While the control plants produced a mean number of 7.86 leaves the number of leaves produced by the plants infested by the grub was 1.33 only. With reference to the reduction in plant height the effect of higher levels of grub population was not much marked. But the tap root length and production of leaves were drastically reduced by the increasing number of grubs around the plant (Plate VIII a and b). The weight of top growth and underground growth also were similarly affected.

Table 8. Extent of damage done to cacao (*Theobroma cacao*) by different levels of grub population of *L. consephora*.

	No. of grubs/plant				CD
	0	1	2	3	
Height (cm)	52.13[a]	44.53[b]	40.40[c]	40.40[c]	2.60
No. of leaves emerging after introduction of grubs.	7.86[a]	1.33[b]	0.13[c]	0.00[c]	0.70
Length of tap root (cm)	25.27[a]	17.40[b]	12.87[c]	6.00[d]	2.16
Weight of top growth (g)	19.88[a]	13.95[b]	9.51[c]	6.53[d]	0.98
Weight of underground growth (g)	9.59[a]	6.33[b]	3.19[c]	1.94[d]	0.84

Notations with different letters indicate significant differences at 1% level.

Fig. 6. Extent of damage done to cacao (*Theobroma cacao*) by different levels of grub population of *L. coneophora*.

FIG.6.

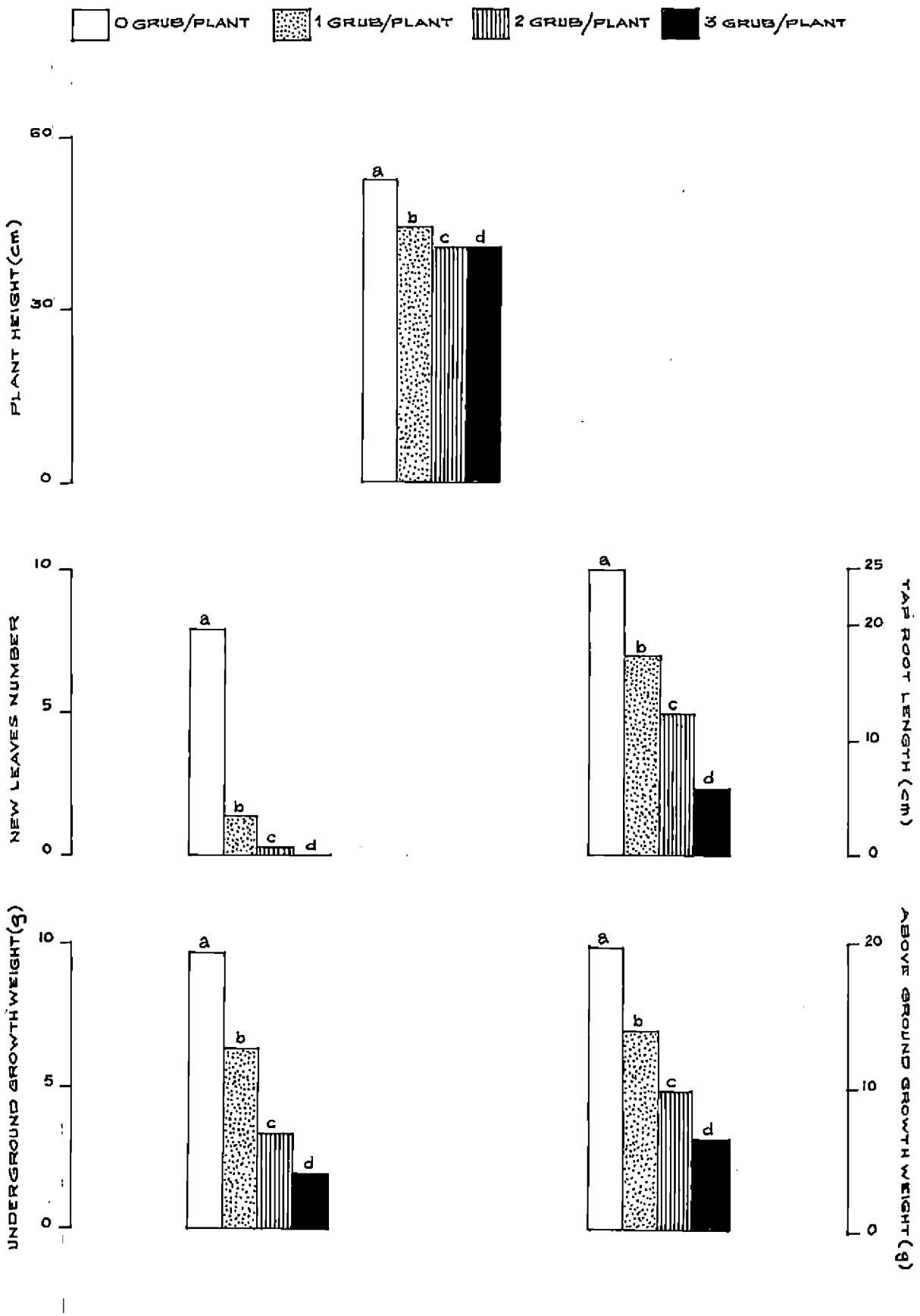

0 GRUB/PLANT
1 GRUB/PLANT
2 GRUB/PLANT
3 GRUB/PLANT
PLANT HEIGHT (cm)
60
30
0
a
b
c
d
NEW LEAVES NUMBER
10
5
0
TAP ROOT LENGTH (cm)
25
20
10
0
UNDERGROUND GROWTH WEIGHT (g)
ABOVE GROUND GROWTH WEIGHT (g)
20

Plate VIII. Nature of damage on cacao (*Theobroma cacao*) caused by *L. coneophora*.

a) seedling

b) healthy root, lateral root destroyed and tap root damaged

a

3.3.3 Wild sunn-hemp (*Crotalaria striata* DC.).

The plants were exposed to the insect at the rate of one grub per plant only since the higher levels of pest population killed the plants outright. Table 9 and Fig. 7 showed that the mean height of the plants exposed to the grub was 90.6 cm only as against a mean height of 165.06 cm for the control plants. When the unaffected plants had 32.93 branches and 203.6 leaves, on an average, the plants exposed to the grubs had 13.33 branches and 44.8 leaves, respectively. The length of the tap root also was drastically reduced (Plate IX a), the mean lengths in control and treatment being 98.26 and 25.46 cm, respectively. The mean weights of the above ground and underground growth of control plants were 67.2 and 45.91 g, while the weights of the treated plants were 25.39 and 8.73 g, respectively. The tap roots and lateral roots were seen cut at different lengths. Even when the tap root was not eaten up by the grub the growth was seen adversely affected. The dearth of irrigation hastened the manifestation of the symptoms of infestation. The leaves drooped and gradually turned yellowish (Plate IX b). However, at the population level of one grub per plant, total mortality of the plant was not noticed.

Table 9. Extent of damage done to wild sunn-hemp (Crotalaria striata) by grub of L. conicephora.

	mean values of		
	plants undamaged	plants damaged	CD
Height (cm)	165.06[a]	90.60[b]	7.25
No. of branches at harvest	32.93[a]	13.33[b]	2.69
No. of leaves at harvest	203.60[a]	44.86[b]	15.45
Length of tap root (cm)	98.26[a]	25.46[b]	8.58
Weight of top growth (g)	67.20[a]	25.39[b]	7.17
Weight of underground growth (g)	45.91[a]	8.73[b]	3.50

Notations with different letters indicate significant differences at 1% level except at the last item where the difference was at 5% level.

Fig. 7. Extent of damage done to wild sunn-hemp (*Crotalaria striata*) by grub of *L. coneophora*.

FIG.7.

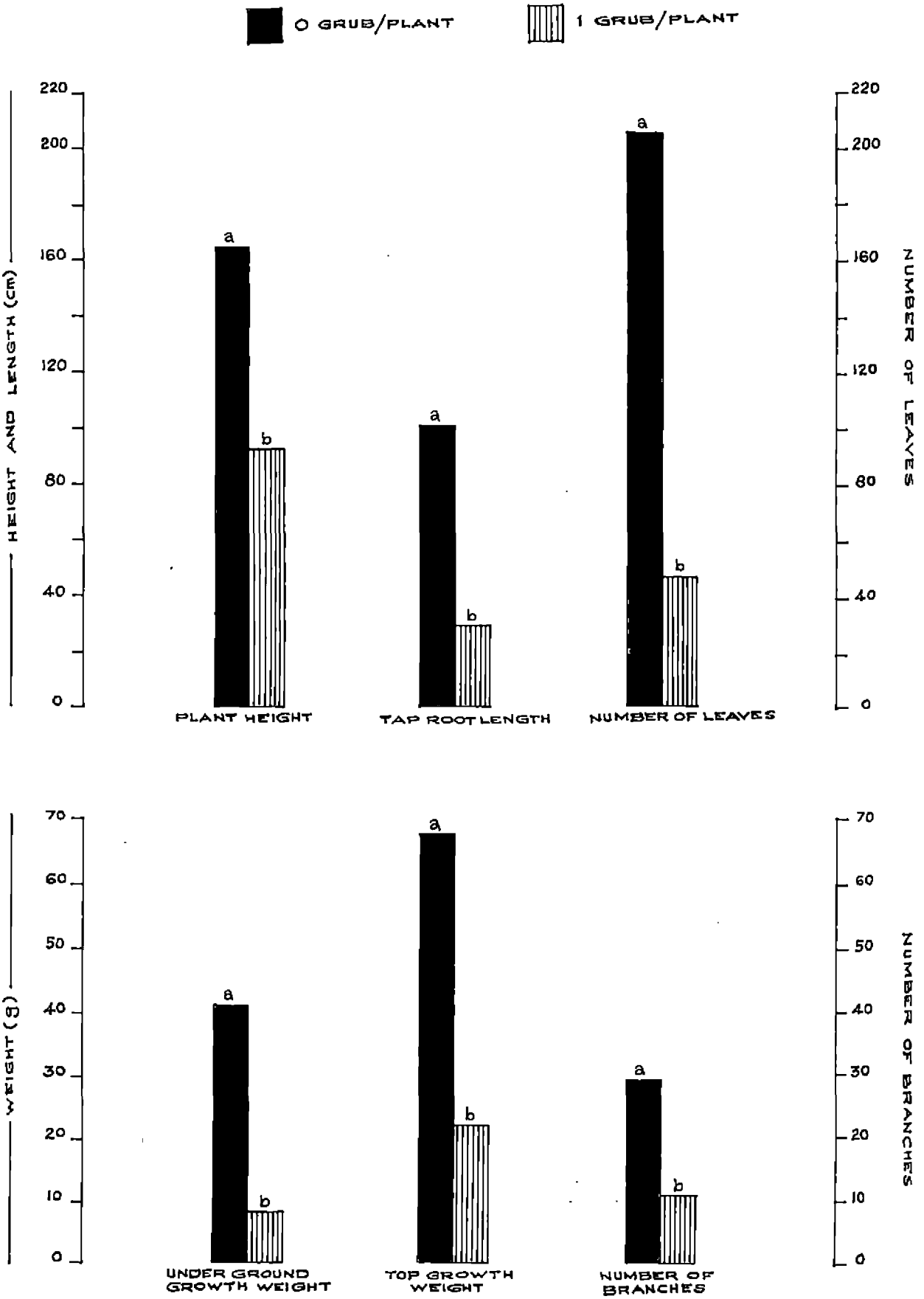
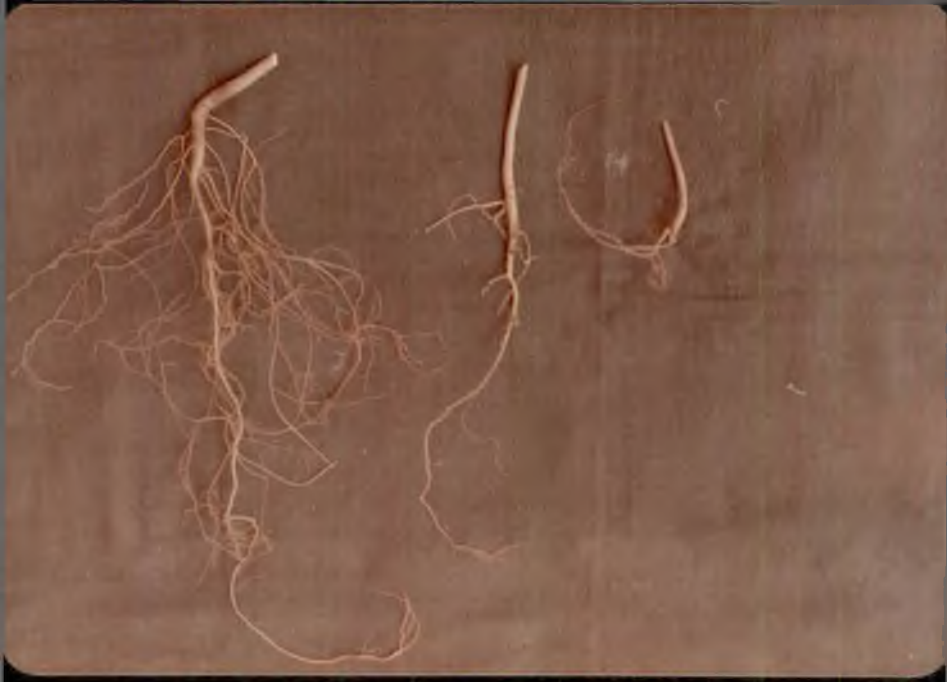

0 GRUB/PLANT
1 GRUB/PLANT
HEIGHT AND LENGTH (cm)
NUMBER OF LEAVES
0
40
80
120
160
200
220
a
b
PLANT HEIGHT
TAP ROOT LENGTH
NUMBER OF LEAVES
WEIGHT (g)
NUMBER OF BRANCHES
0
10
20
30
40
50
60
70
UNDER GROUND GROWTH WEIGHT
TOP GROWTH WEIGHT
NUMBER OF BRANCHES

Plate IX. Nature of damage on wild sunn-hemp (*Crotalaria striata*) caused by *L. coneophora*.

a) healthy root, lateral root destroyed and tap root damaged

b) healthy and damaged plants



a

b

3.3.4 Coconut palm (*Cocos nucifera* Linn.).

In the nursery the grubs were seen feeding on the tip portion of the roots only where the tissue is soft. When such roots were fully consumed the grubs moved to the collar region of the seedlings and tunnelled into the soft growing plumule (Plate X a). This type of damage caused the drying of spindle leaf followed by yellowing of the outer leaves and gradual death of the seedling.

The palms in the gardens reported as pest infested since 1952 showed characteristic aerial symptoms like yellowing of entire leaves up to the inner whorl.

In the infested garden the fresh roots emerging from the bole region were seen eaten away. The growing point of the older roots were also seen eaten up (Plate X b). In badly infested gardens which suffered a continuous attack of the pest for years the leaves became sickly yellow, flowering was delayed, formation of nuts reduced and immature nutfall occurred and thus the yield got reduced (Plate XI a and b). In 4-5 year-old palms even when a heavy population of grubs was seen at the bottom the above aerial symptoms were not clearly manifested.

Plate X. Nature of damage on coconut palm (*Cocos nucifera*) caused by *L. concophora*.

a) coconut seedling, root damaged and collar region tunnelled by grubs

b) healthy and damaged roots

a

b

Plate XI. Nature of damage on coconut palm (*Cocos nucifera*) caused by *L. coneophora* (continuation).

a) an infested coconut garden

b) a coconut palm in a severely infested garden

a

b

3.4 Distribution of the life stages of L. coneophora in different depths of soil and their seasonal occurrence

3.4.1 Distribution of population in different depths of soil.

Adults.

The mean percentage of the adults in different depths of soil observed at fortnightly intervals is recorded in Table 10 and Fig. 8. In both the locations beetle population was seen low in the depth of 0-15 cm. In Thazhakkara in 1978 and 1979 no beetle was collected from this depth, while in 1980 low level of 6.7 per cent of the population was found in the above depth. The populations at 0-15 cm depth at Vazhuvadi during 1978, 1979 and 1980 were 4.3, 0 and 2.0 per cent, respectively. In the second depth of 15-30 cm also the beetle population was relatively low. At Thazhakkara the total populations at the depths of 30-100 cm were 79.10, 87.5 and 82.4 per cent during 1978, 1979 and 1980, respectively, while at Vazhuvadi the populations at the depth during the three years were 95.7, 72.7 and 81.7 per cent, respectively. At both the locations, the maximum population observed was in the maximum depth of 60-100 cm during 1978, and 1980, while in 1979 the highest level of population was at the depth ranging from 30-45 cm.

Table 10. Distribution of the adults of L. conesphora in different depths of soil observed during different months at two locations in Alleppey District.

location year	depth of soil (cm)	percentage of population observed in Apr. a	Apr. b	May a	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	total population(%)
Thazhakkara														
1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	0	33	50	100	0	0	0	20.8
	30-45	0	0	0	0	20	0	33	17	0	0	0	0	12.5
	45-60	0	0	0	20	20	75	33	0	0	0	0	0	25.0
	60-100	0	0	0	80	60	25	0	33	0	0	0	0	41.7
1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	0	20	33	25	0	0	0	12.5
	30-45	0	0	0	0	50	33	20	33	50	50	100	100	37.5
	45-60	0	0	0	0	50	22	20	33	0	50	0	0	21.9
	60-100	0	0	0	0	0	44	40	0	25	0	0	0	28.1
1980	0-15	0	0	0	0	0	0	0	10	7	22	0	0	6.7
	15-30	0	0	0	0	0	0	0	10	29	22	0	0	10.8
	30-45	0	0	0	50	50	25	50	33	21	0	0	0	29.7
	45-60	0	0	0	50	20	17	33	14	7	11	0	0	16.2
	60-100	0	0	0	0	30	58	17	33	36	44	0	0	36.5
Vazhuvadi														
1978	0-15	0	0	0	0	0	11	17	0	0	0	0	0	4.3
	15-30	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	30-45	0	0	0	30	50	0	17	20	0	0	0	0	26.1
	45-60	0	0	0	0	0	22	50	40	50	0	0	0	17.4
	60-100	0	0	0	70	50	67	17	40	50	0	0	0	52.2
1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	29	29	42	40	29	0	0	27.3
	30-45	0	0	0	0	45	21	50	17	40	29	50	0	33.3
	45-60	0	0	0	0	45	50	14	17	20	14	50	0	27.3
	60-100	0	0	0	100	10	0	7	25	0	29	0	0	12.1
1980	0-15	0	0	20	0	0	0	0	0	0	0	0	0	2.0
	15-30	100	100	20	0	0	12	0	14	0	50	0	0	16.3
	30-45	0	0	60	17	20	13	20	29	0	0	0	0	20.4
	45-60	0	0	0	50	30	37	40	14	50	0	0	0	26.6
	60-100	0	0	0	33	50	38	40	43	50	50	0	0	34.7

year	total rainfall (mm) April a	April b	May a	May b	June a	June b	July a	July b	August a	August b	September a	September b
1978	42	30	17	231	234	137	250	177	330	129	99	61
1979	14	48	14	22	272	281	153	139	63	70	144	133
1980	43	19	85	92	207	321	306	212	179	88	101	110

a = first fortnight of the month; b = second fortnight of the month.

Fig. 8. Distribution of different life stages of L. coneophora in different depths of soil observed at two locations in Alleppey Dist.

1 adult

2 egg

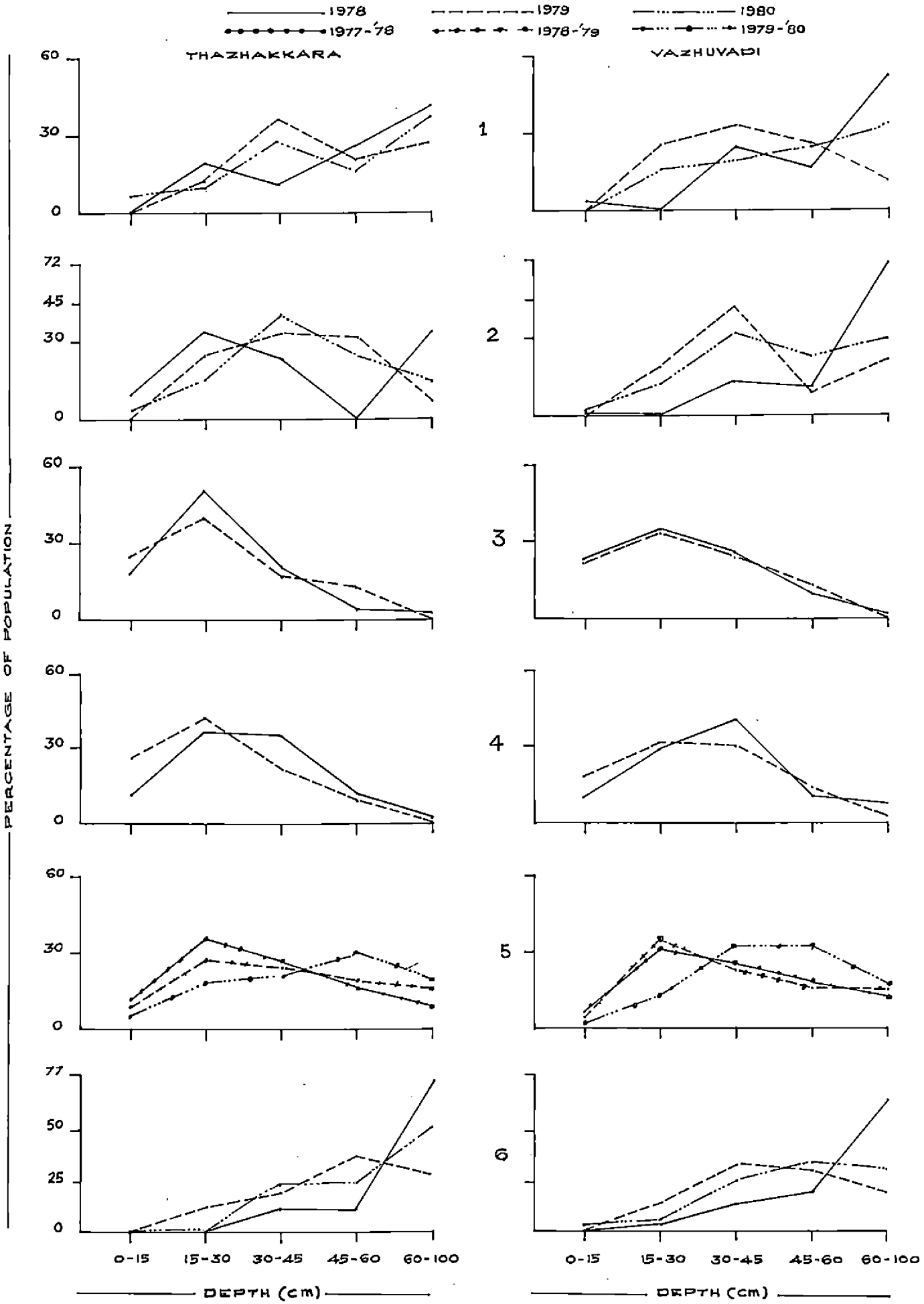
3 first instar grub

4 second instar grub

5 third instar grub

6 pupa

FIG. 8.


1978
1979
1980
1977-'78
1978-'79
1979-'80
THAZHAKKARA
VAZHUVADI
PERCENTAGE OF POPULATION
1
2
3
4
5
6
60
30
0
72
45
30
0
60
30
0
60
30
0
60
30
0
77
50
25
0
0-15
15-30
30-45
45-60
60-100
DEPTH (cm)

Eggs.

Data are shown in Table 11 and Fig. 8. Minimum percentage of eggs was observed at the top layer of 0-15 cm depth the mean number being 0 to 8.7 at Thazhakkara and 0 to 1.0 at Vazhuvadi. At both the locations around 80 per cent of the eggs were collected from 30-100 cm depth except in 1978 at Thazhakkara.

First instar grubs.

The distribution of the first instar grubs is presented in Table 12 and Fig. 8. The population was least in the deepest layer of 60-100 cm being absent in many observations and the mean percentages were 3.8 and 1.7 during 1978 and 1979, respectively, at Thazhakkara and 2.9 and 2.6 at Vazhuvadi. The mean populations in the next higher level of 45-60 cm also were relatively lower, these being 5.1 and 14.6 for Thazhakkara and 10.3 and 13.6 for Vazhuvadi during 1978 and 1979, respectively. The highest percentages of population were observed in the second depth range of 15-30 cm in both the locations during 1978 and 1979 the percentages being 50.6, 40.4, 35.4 and 33.8, respectively. During 1978, a higher population (21.3 per cent) was observed at 30-45 cm depth than at 0-15 cm (19.1 per cent), whereas in 1979 the depth of 0-15 cm had a higher percentage of population

Table 11. Distribution of the eggs of L. cenaephora in different depths of soil observed during different months at two locations in Alleppey District.

location / year	depth of soil (cm)	percentage of population observed in May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	total population(%)
Thazhakkara											
1978	0-15	0	0	33	19	0	0	0	0	0	8.7
	15-30	0	11	67	60	31	0	0	0	0	32.9
	30-45	0	34	0	21	0	100	0	0	0	23.7
	45-60	0	0	0	0	0	0	0	0	0	0.0
	60-100	100	54	0	0	69	0	0	0	0	34.7
1979	0-15	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	8	20	0	46	48	44	0	0	24.5
	30-45	0	49	35	54	44	0	4	0	0	33.9
	45-60	0	0	45	46	0	52	52	0	0	33.2
	60-100	0	43	0	0	10	0	0	0	0	8.3
1980	0-15	9	0	16	0	0	0	3	0	0	2.1
	15-30	0	11	41	0	45	0	15	0	0	15.8
	30-45	0	41	44	50	30	52	38	0	0	41.1
	45-60	0	0	0	38	0	48	45	0	0	25.2
	60-100	91	48	0	12	25	0	0	0	0	15.5
Vazhuvadi											
1978	0-15	0	1	0	0	0	0	0	0	0	0.4
	15-30	0	0	0	0	0	0	0	0	0	0.0
	30-45	0	10	0	41	10	100	0	0	0	15.1
	45-60	5	0	0	59	65	0	0	0	0	13.5
	60-100	95	89	0	0	25	0	0	0	0	70.9
1979	0-15	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	3	4	46	0	43	28	45	20.4
	30-45	0	16	4	56	54	100	57	60	55	45.3
	45-60	0	0	41	12	0	0	0	12	0	9.3
	60-100	0	84	53	28	0	0	0	0	0	24.8
1980	0-15	3	3	0	0	3	0	0	0	0	1.0
	15-30	61	0	0	0	0	0	45	0	0	13.1
	30-45	36	15	26	12	44	60	55	0	0	34.1
	45-60	0	0	16	54	54	40	0	0	0	22.1
	60-100	0	82	58	34	0	0	0	0	0	29.6

	total rainfall (mm)								
	May	June		July		August		September	
	b	a	b	a	b	a	b	a	b
1978	231	234	137	250	177	330	129	99	61
1979	22	272	281	153	139	63	70	144	133
1980	92	207	321	306	212	179	88	101	110

a = first fortnight of the month; b = second fortnight of the month

Table 12. Distribution of the first instar grubs of L. concophora in different depths of soil observed during different months at two locations in Alleppey District.

location year	depth of soil (cm)	percentage of population observed in May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	total population(%)
Thazhakkara												
1978	0-15	67	0	0	20	28	23	16	19	18	29	19.1
	15-30	33	75	33	30	64	55	51	53	45	57	50.6
	30-45	0	25	53	50	4	3	31	11	29	14	21.3
	45-60	0	0	6	0	4	0	2	13	8	0	5.1
	60-100	0	0	7	0	0	19	0	4	0	0	3.8
1979	0-15	0	80	0	29	48	46	33	19	0	0	25.0
	15-30	0	20	20	46	37	46	47	52	30	100	40.4
	30-45	0	0	35	18	4	8	11	12	70	0	18.3
	45-60	0	0	45	5	4	0	8	15	0	0	14.6
	60-100	0	0	0	3	7	0	0	2	0	0	1.7
Vaghuvadi												
1978	0-15	23	17	13	23	19	29	35	17	23	0	24.0
	15-30	23	50	37	30	48	47	35	17	15	60	35.4
	30-45	0	33	37	30	30	24	25	33	54	0	27.4
	45-60	46	0	13	13	4	0	5	8	8	40	10.3
	60-100	8	0	0	3	0	0	0	25	0	0	2.9
1979	0-15	0	40	15	12	14	17	39	53	20	14	23.4
	15-30	0	40	31	44	27	43	17	42	13	57	33.8
	30-45	0	20	46	16	41	39	17	5	27	14	26.6
	45-60	0	0	8	28	17	0	17	0	27	14	13.6
	60-100	0	0	0	0	0	0	11	0	13	0	2.6

total rainfall (mm)

	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a
1978	231	234	137	250	177	330	129	99	61	27
1979	22	272	281	153	139	63	70	144	133	101

a = first fortnight of the month; b = second fortnight of the month

(25 per cent) than 30-45 cm depth (18.3 per cent). But at Vazhuvadi during 1978 and 1979, 0-15 cm depths had less population (24 and 23.4 per cent, respectively) than in depths of 30-45 cm (27.4 and 26.6 per cent, respectively).

Second instar grubs.

Data relating to the population of the second instar grubs are presented in Table 13 and Fig. 8. The mean population was maximum at 15-30 cm at Thazhakkara during 1978 and 1979, percentages being 35.8 and 40.2, respectively. It was followed by the deeper layer of 30-45 cm during 1978 (34.9 per cent), while in 0-15 cm depth the population was low (11.3 per cent). During 1979 in 0-15 cm there was 24.4 per cent of the population while at 30-45 cm depth it was 22.8 per cent only. At the deeper depths of 45-60 and 60-100 cm , the percentages of population in 1978 were 12.3 and 5.7 per cent, respectively, and in 1979 the same wore 11.8 and 0.8 per cent, respectively.

At Vazhuvadi during 1978 the higher population (40.0 per cent) was observed at 30-45 cm and the population was less at 15-30 cm (29.4 per cent) and 0-15 cm depths (11.7 per cent). But in 1979, the highest population level was at 15-30 cm depth (45.5 per cent) and it was followed by the populations at 30-45 cm depth (30.3 per cent) and 0-15 cm depth (15.2 per cent). During 1978 and 1979 the population level at 45-60 and 60-100 cm depths were

Table 13. Distribution of the second instar grubs of L. semnophora in different depths of soil observed during different months at two locations in Alleppey District.

location / year	depth of soil (cm)	percentage of population observed in Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	Oct. b	Nov. a	total population(%)
Thazhakkara											
1978	0-15	0	12	14	0	7	18	29	17	0	11.3
	15-30	0	75	72	17	3	47	57	39	62	35.8
	30-45	0	12	14	25	62	18	14	39	38	34.9
	45-60	0	0	0	8	28	18	0	6	0	12.3
	60-100	0	0	0	50	0	0	0	0	0	5.7
1979	0-15	67	11	33	46	32	9	0	12	50	24.4
	15-30	33	78	44	31	3	64	70	58	50	40.2
	30-45	0	11	11	15	45	14	20	18	0	22.8
	45-60	0	0	11	8	21	14	10	6	0	11.8
	60-100	0	0	0	0	0	0	0	6	0	0.8
Vazhavadi											
1978	0-15	0	0	45	0	7	33	0	0	0	11.7
	15-30	50	18	55	44	7	33	14	25	40	29.4
	30-45	50	64	0	11	67	25	71	63	20	40.00
	45-60	0	9	0	33	0	8	14	12	20	10.6
	60-100	0	9	0	11	19	0	0	0	20	8.2
1979	0-15	0	0	40	50	0	20	20	7	0	15.2
	15-30	0	0	0	12	100	40	40	27	100	45.5
	30-45	0	0	60	38	0	20	20	40	0	30.3
	45-60	0	0	0	0	0	20	20	20	0	6.1
	60-100	0	0	0	0	0	0	0	7	0	3.0

total rainfall (mm)

	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	Oct. b	Nov. a
1978	250	177	330	129	99	61	27	255	255
1979	153	139	63	70	144	133	101	28	98

a = first fortnight of the month; b = second fortnight of the month.

relatively low ranging from 3.0 to 10.6 per cent only. Except in a very few occasions second instar grubs were not recorded in deeper levels of 60-100 cm and in many observations they were lacking at 45-60 cm depth also.

Third instar grubs.

The populations at different depths are presented in Table 14 and Fig. 8. Maximum population was seen at 15-30 cm depth during 1977-78 and 1978-79 at Thazhakkara (35.8 per cent). The population was in a descending scale at depths of 30-45 (26.1 per cent), 45-60 (17.4 per cent), 0-15 (11.8 per cent) and 60-100 cm (8.7 per cent) during 1977-78. During 1978-79 also the same trend was observed. But in 1979-80 the highest population was recorded at 45-60 cm depth (29.5 per cent) and the population showed relatively lower trends at depths of 30-45 cm (24.8 per cent), 60-100 cm (20.5 per cent), 15-30 cm (18.2 per cent) and 0-15 cm (6.9 per cent), respectively.

At Vazhuvadi also high population level was observed at depths of 15-30 cm (32.3 per cent) and 30-45 cm (27.4 per cent) during 1977-78 and the same trend (35.3 per cent and 24.6 per cent) was seen in 1978-79 also. But during 1979-80 the highest population levels (31.9 per cent) was observed at 30-45 and 45-60 cm depths. The population levels in other strata were relatively low ranging from

Table 14. Distribution of the third instar grubs of L. caesophora in different

location / year	depth of soil (cm)	percentage Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara									
1977-78	0-15	100	20	0	20	11	21	0	0
	15-30	0	48	35	36	41	43	6	23
	30-45	0	17	25	30	30	25	35	31
	45-60	0	10	30	15	15	11	47	15
	60-100	0	5	10	0	4	0	12	31
1978-79	0-15	0	0	0	15	14	20	10	13
	15-30	0	0	23	38	25	30	20	34
	30-45	0	50	41	29	25	40	40	20
	45-60	67	50	23	9	25	10	20	13
	60-100	33	0	17	9	11	0	10	20
1979-80	0-15	0	0	0	18	11	13	5	12
	15-30	50	50	22	38	26	27	15	29
	30-45	50	50	48	26	30	20	40	29
	45-60	0	0	17	9	26	20	35	18
	60-100	0	0	13	9	7	20	5	12
Vazhuvadi									
1977-78	0-15	0	13	0	14	12	12	12	0
	15-30	0	73	40	40	35	35	6	13
	30-45	0	13	14	14	12	19	24	27
	45-60	0	0	14	20	41	23	41	60
	60-100	0	0	31	11	0	12	18	0
1978-79	0-15	0	0	0	0	0	0	22	7
	15-30	29	11	23	38	18	33	22	29
	30-45	43	67	36	25	47	33	0	43
	45-60	14	22	27	38	18	14	6	0
	60-100	14	0	14	0	18	19	50	21
1979-80	0-15	14	9	12	0	4	15	7	10
	15-30	0	0	25	43	21	35	14	10
	30-45	43	54	50	43	33	15	29	20
	45-60	14	27	12	14	33	25	50	40
	60-100	19	9	0	0	8	10	0	20

	October a	October b	November a	November b	December a	December b	total January a
1977-78	150	287	249	196	27	29	0
1978-79	27	255	255	362	127	25	6
1979-80	101	28	98	145	74	11	

a = first fortnight of the month; b = second fortnight of the mo

depths of soil observed during different months at two locations in Alleppey Dist.

population observed in												total population(%)
Feb.		Mar.		Apr.		May		Jun.		Jul.		
a	b	a	b	a	b	a	b	a	b	a	b	
0	3	6	14	8	18	17	17	0	0	0	0	11.8
0	25	24	41	54	44	58	29	0	0	18	0	35.8
20	17	35	31	29	29	25	17	17	50	36	0	26.1
53	19	35	12	8	6	0	21	33	50	36	0	17.4
27	36	0	2	0	3	0	17	50	0	9	0	8.7
0	12	0	0	0	9	26	0	0	0	0	0	9.8
7	31	21	21	50	36	58	50	0	0	18	0	28.2
14	6	42	16	0	9	0	0	17	50	36	0	25.5
14	19	26	21	0	18	11	50	33	50	36	0	18.8
64	31	11	42	50	27	5	0	50	0.	9	0	18.0
12	12	0	0	0	0	0	0	0	0	0	0	6.9
6	12	7	8	0	0	38	0	0	0	0	0	18.2
24	18	7	8	5	15	12	40	50	33	0	0	24.8
47	29	29	67	55	35	50	20	0	33	0	0	29.5
12	29	57	17	40	50	0	40	50	33	0	0	20.5
0	8	19	7	0	11	17	0	0	0	0	0	7.6
20	31	25	25	31	22	59	0	40	0	0	0	32.3
53	38	44	32	69	56	25	9	50	50	0	0	27.4
20	8	6	11	0	11	0	9	10	50	0	0	18.4
7	15	6	25	0	0	0	82	0	0	0	0	14.2
0	9	0	4	10	22	0	20	0	0	0	0	6.5
25	32	8	7	40	68	60	20	37	67	100	100	35.3
0	18	21	25	30	7	20	20	63	33	0	0	24.6
50	18	37	46	10	2	20	40	0	0	0	0	18.5
25	23	33	18	10	0	0	0	0	0	0	0	15.1
0	0	0	0	0	0	50	0	0	0	0	0	4.8
0	0	5	0	20	20	50	0	33	0	0	0	14.3
21	30	42	37	20	40	0	0	42	40	0	0	31.9
57	30	26	47	40	40	0	12	17	20	0	0	31.9
21	40	26	16	20	0	0	88	8	40	0	0	17.1

rainfall (mm)

February		March		April		May		June		July	
a	b	a	b	a	b	a	b	a	b	a	b
5	18	12	29	42	30	17	231	234	137	250	177
0	14	0	24	14	48	14	22	272	281	153	139
0	0	8	30	43	19	85	92	207	321	306	212

7.6 to 18.4 per cent, 6.5 to 18.5 per cent and 4.8 to 17.1 per cent during 1977-78, 1978-79 and 1979-80, respectively.

Pupal instar.

The distribution of pupae in different depths of the soil is presented in Table 15 and Fig. 8. At Thazhakkara no pupae were found in the upper strata of 0-15 cm depth during the entire period of observation and except in the year 1979 pupae were not present at the depth of 15-30 cm also. Pupae were collected from the depths of 30-100 cm during all the years. The mean percentage of pupae present at the depths of 30-45 cm, 45-60 cm and 60-100 cm ranged from 12.9 to 24.1 per cent, 9.6 to 37.5 per cent and 29.2 to 77.4 per cent, respectively.

During 1978 and 1979 pupae were not collected from the top strata of 0-15 cm depth at Vazhuvadi, while in 1980 a small percentage (3.4 per cent) was found in that strata. In the depth of 15-30 cm the percentage of pupae present ranged from 4.4 to 15.1. In the strata of 30-45 cm, 45-60 cm and 60-100 cm the percentage ranged from 11.7 to 32.7, 19.1 to 34.0 and 20.7 to 64.7, respectively. The highest level of pupae was found in the deepest strata of 60-100 cm.

Table 15. Distribution of the pupae of L. consophora in different depths of soil observed during different months at two locations in Alleppey District.

location year	depth of soil (cm)	percentage of population observed in Mar. a	Mar. b	Apr. a	Apr. b	May a	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	total population(%)
Thazhakkara														
1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	30-45	0	0	0	0	29	0	0	100	0	100	0	0	12.9
	45-60	0	0	0	0	0	15	0	0	25	0	0	0	9.6
	60-100	0	0	0	0	71	85	100	0	75	0	0	0	77.4
1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	0	0	23	0	100	0	0	12.5
	30-45	0	0	0	50	25	0	0	15	36	0	33	50	20.8
	45-60	0	0	100	50	0	67	60	8	64	0	33	50	37.5
	60-100	0	0	0	0	75	33	40	54	0	0	33	0	29.2
1980	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	30-45	0	0	25	20	33	80	22	25	0	12	0	0	24.1
	45-60	0	0	25	40	33	20	11	19	22	38	0	0	24.1
	60-100	0	0	50	40	33	0	67	56	78	50	0	0	51.6
Vazhuvadi														
1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	20	9	0	0	0	0	0	0	4.4
	30-45	0	0	0	0	0	13	8	20	33	0	0	0	11.7
	45-60	0	0	0	0	20	0	28	30	67	0	0	0	19.1
	60-100	0	0	0	0	60	78	64	50	0	0	100	0	64.7
1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	15-30	0	0	0	0	0	0	0	33	50	38	0	0	15.5
	30-45	0	0	0	0	33	0	37	56	33	38	0	0	32.7
	45-60	100	100	0	100	33	67	23	11	0	25	0	0	31.0
	60-100	0	0	0	0	33	33	41	0	17	0	0	0	20.7
1980	0-15	0	0	9	9	0	0	0	0	0	0	0	0	3.4
	15-30	0	0	9	0	29	0	0	0	0	0	0	0	4.5
	30-45	50	50	18	27	57	25	11	8	50	50	0	0	25.0
	45-60	25	50	18	64	14	75	39	33	25	0	0	0	34.0
	60-100	25	0	46	0	0	0	50	58	25	50	0	0	32.9

total rainfall (mm)

	March a	March b	April a	April b	May a	May b	June a	June b	July a	July b	August a	August b
1978	12	29	42	30	17	231	234	137	250	177	330	129
1979	0	24	14	48	14	22	272	281	153	139	63	70
1980	8	30	43	19	85	92	207	321	306	212	179	88

a = first fortnight of the month; b = second fortnight of the month

3.4.2 Influence of soil temperature and soil moisture on the distribution of the life stages of L. coneophora.

The distribution of the beetles and different instars of grubs of L. coneophora is shown in Fig. 9 and 10. Maximum number of beetle population was seen in the temperature range of 29-31°C and soil moisture of 9-11 per cent. In the case of first instar grubs the highest mean number (52) was observed in the temperature range of 29-31°C and soil moisture range of 8-10 per cent. The peak mean population of second instar grubs (37.5) was observed in the temperature range of 31-33°C and soil moisture of 8-10 per cent. Third instar grub also preferred the temperature range of 31-33°C (mean number 66) and moisture range of 7-9 per cent.

3.4.3 Seasonal distribution of the life stages of L. coneophora.

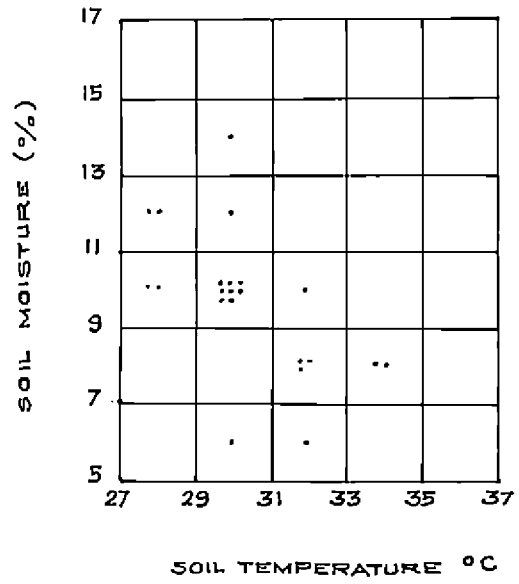
Data relating to the seasonal distribution of life stages of L. coneophora are presented in Tables 16 and 17 and Fig. 11. The adults were generally seen in soil from the second half of May to the end of August. But, at Vazhuvadi during 1980 beetles were collected from the first half of April onwards. The beetle population remained high from the second half of May to the end of July during 1978 at both the locations. During 1979

Fig. 9. Mean number of adults and first instar grubs of *L. coneophora* observed in different ranges of soil temperature and moisture.

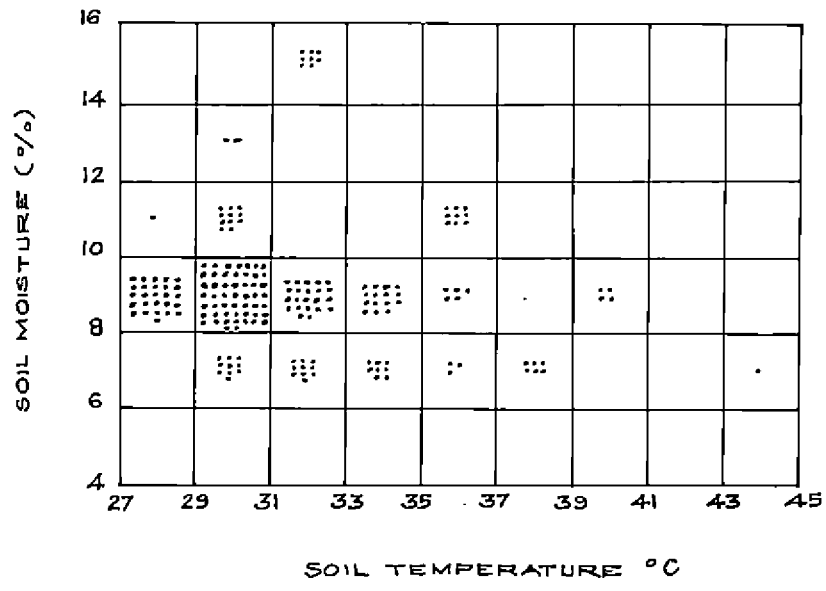
a) adults

b) first instar grubs

FIG. 9


17
15
13
11
9
7
5
SOIL MOISTURE (%)
27
29
31
33
35
37
SOIL TEMPERATURE °C

a


16
14
12
10
8
6
4
SOIL MOISTURE (%)
27
29
31
33
35
37
39
41
43
45
SOIL TEMPERATURE °C

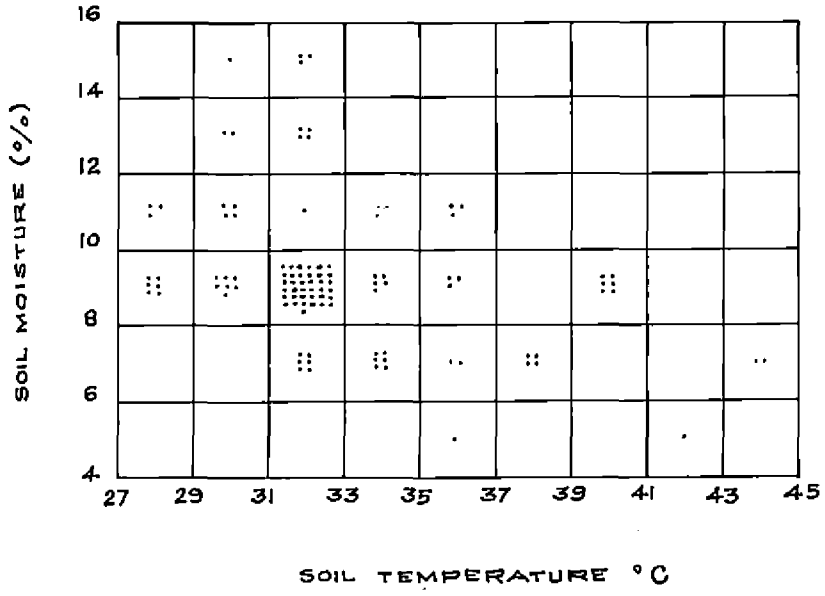
b

Fig. 10. Mean number of second and third instar grubs of L. coneophora observed in different ranges of soil temperature and moisture.

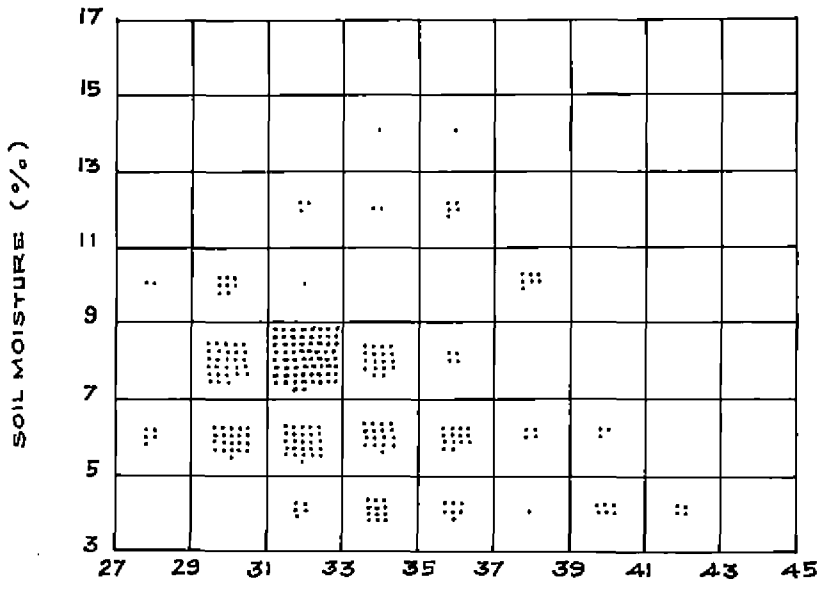
a) second instar grubs

b) third instar grubs

FIG. 10


SOIL MOISTURE (%)
16
14
12
10
8
6
4
27 29 31 33 35 37 39 41 43 45
SOIL TEMPERATURE °C

a


SOIL MOISTURE (%)
17
15
13
11
9
7
5
3
27 29 31 33 35 37 39 41 43 45
SOIL TEMPERATURE °C

b

Table 16. Seasonal occurrence of the adults, eggs, first instar grubs

life stage	location / year	number observed					
		April		May		June	
		a	b	a	b	a	b
Adult	Thazhakkara						
	1978	0	0	0	5	5	4
	1979	0	0	0	0	2	9
	1980	0	0	0	0	10	12
	mean	0.0	0.0	0.0	2.3	5.6	8.3
	Vazhuvadi						
	1978	0	0	0	10	14	9
	1979	0	0	0	1	11	14
	1980	2	2	5	6	10	8
	mean	0.6	0.6	1.6	5.7	11.6	10.3
Egg	Thazhakkara						
	1978				16.	35	15
	1979				0	39	49
	1980				11	44	32
	mean				9.0	27.6	32.0
	Vazhuvadi						
	1978				90	92	0
	1979				0	69	78
	1980				36	62	69
	mean				42.0	74.3	49.0
First instar grub	Thazhakkara						
	1978				3	4	15
	1979				0	5	49
	mean				1.5	4.5	32.0
	Vazhuvadi						
	1978				13	6	8
	1979				0	5	13
	mean				6.5	5.5	10.5
Second instar grub	Thazhakkara						
	1978						
	1979						
	mean						
	Vazhuvadi						
	1978						
	1979						
	mean						

a = first fortnight of the month
b = second fortnight of the month

and second instar grubs of L. consephora in coconut gardens at two locations.

in the month of									
July		August		September		October		November	
a	b	a	b	a	b	a	b	a	b
3	6	1	0	0	0				
10	3	4	2	1	1				
6	21	14	9	0	0				
6.3	10.0	6.3	3.6	0.3	0.3				
6	5	2	0	0	0				
14	12	5	7	2	0				
5	7	2	2	0	0				
8.3	8.0	3.0	3.0	0.7	0.0				
53	36	18	0	0	0				
59	39	44	23	0	0				
80	67	64	74	0	0				
64.0	47.4	42.0	32.3	0.0	0.0				
27	20	15	0	0	0				
25	55	51	53	40	55				
56	39	50	60	0	0				
36.0	38.0	38.6	37.6	13.3	18.3				
10	25	31	55	47	38	7			
39	27	24	36	48	10	2			
24.5	26.0	27.5	45.5	47.5	24.0	4.5			
30	27	21	40	12	13	5			
25	29	23	18	19	15	7			
27.5	28.0	22.0	29.0	15.5	24.0	6.0			
0	8	7	12	29	17	7	18	8	0
3	9	9	13	38	22	10	17	6	6
1.5	8.5	8.0	12.5	33.5	19.5	8.5	17.5	7.0	3.0
2	11	11	9	15	12	7	8	10	0
0	0	5	8	2	15	5	15	7	0
1.0	5.5	8.0	8.5	8.5	15.5	6.0	11.5	8.5	0.0

Table 17. Seasonal occurrence of the third instar grubs and

life stage	location / year	number observed									
		Oct.		Nov.		Dec.		Jan.		Feb.	
		a	b	a	b	a	b	a	b	a	b
third instar grub	Thazhakkara										
	1977-78	1	60	20	61	54	28	17	13	15	36
	1978-79	3	4	22	34	28	20	20	15	14	16
	1979-80	2	2	23	34	27	15	20	17	17	17
	mean	2.0	22.6	21.6	43.0	36.3	21.0	19.0	15.0	15.3	23.0
	Vazhuvadi										
	1977-78	0	15	35	35	17	26	17	15	15	13
	1978-79	7	9	22	8	17	21	18	14	8	22
	1979-80	7	11	8	7	24	20	14	10	14	10
	mean	4.6	11.6	21.6	16.6	19.3	22.3	16.3	13.0	12.3	15.0
pupa	Thazhakkara										
	1978										
	1979										
	1980										
	mean										
	Vazhuvadi										
	1978										
	1979										
	1980										
	mean										

a = first fortnight of the month
b = second fortnight of the month

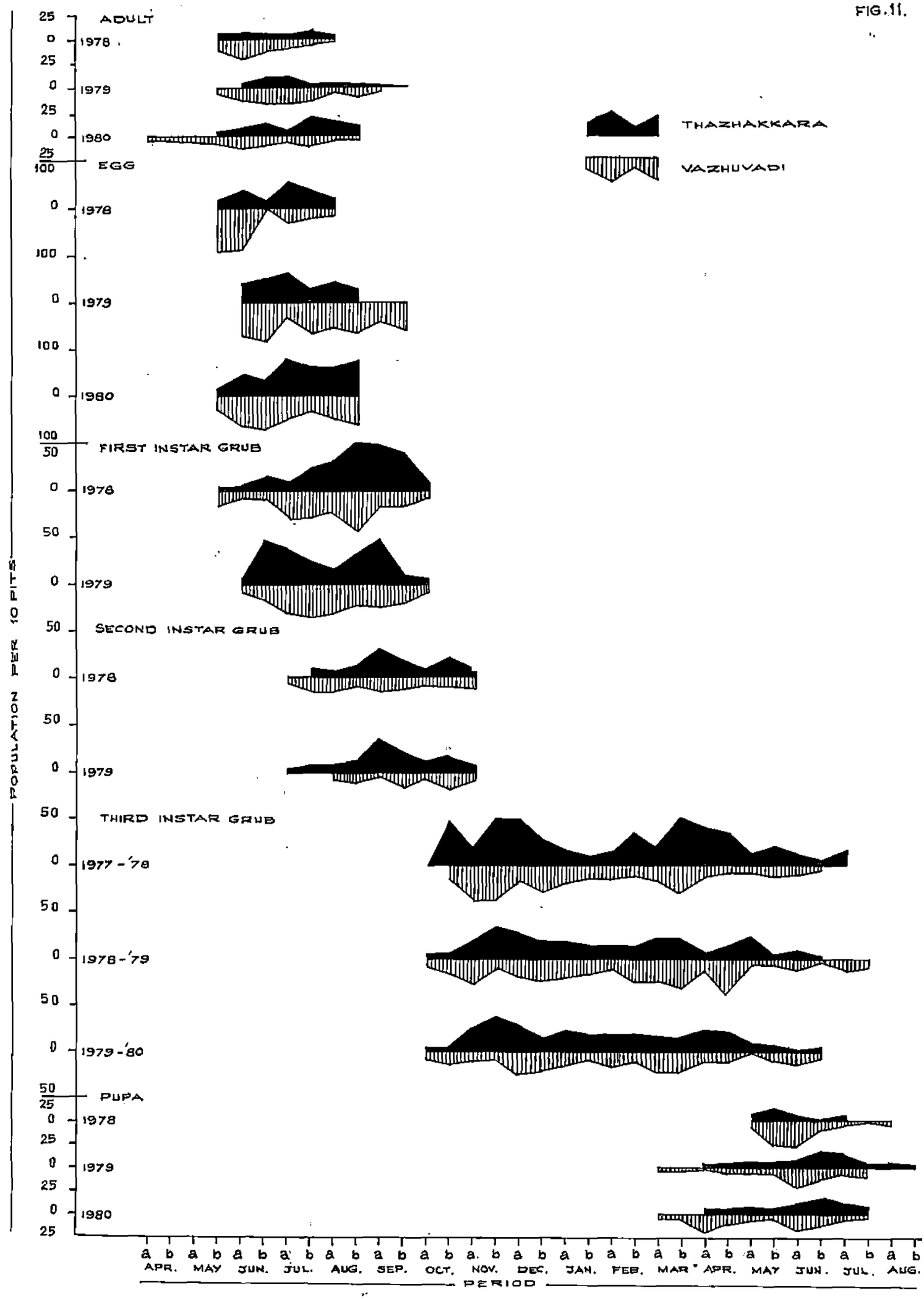
Fig. 11. Seasonal occurrence of different life stages of L. coneophora.

Fig. 11. Seasonal occurrence of different life stages of *L. coneophora*.

pupae of L. coneophora in coconut gardens at two locations.

in the month of											
Mar.		Apr.		May		Jun.		Jul.		Aug.	
a	b	a	b	a	b	a	b	a	b	a	b
17	51	37	34	12	24	12	2	11	0		
19	19	2	11	19	2	7	1	0	0		
14	12	20	20	8	5	2	3	0	0		
16.6	27.3	23.0	10.3	13.0	10.3	7.0	2.0	3.7	0.0		
16	28	13	9	9	11	10	4	0	0		
24	28	10	41	5	5	11	3	12	7		
19	19	10	10	2	8	12	5	0	0		
19.6	25.0	11.0	20.0	5.3	8.0	11.0	4.0	4.0	2.3		
0	0	0	0	7	13	5	1	4	1	0	0
0	0	2	2	4	3	5	13	11	3	3	2
0	0	4	5	6	5	9	16	9	8	0	0
0.0	0.0	2.0	2.3	5.6	7.0	6.3	10.0	8.0	4.0	1.0	0.6
0	0	0	0	5	23	25	10	3	0	2	0
1	2	0	4	3	3	22	9	6	8	0	0
4	4	22	11	7	4	18	12	4	2	0	0
1.6	2.0	7.3	5.0	5.0	10.0	21.6	10.3	4.3	3.3	0.6	0.0

FIG. 11.


ADULT
1978
1979
1980
EGG
FIRST INSTAR GRUB
SECOND INSTAR GRUB
THIRD INSTAR GRUB
1977 - '78
1978 - '79
1979 - '80
PUPA
THAZHAKKARA
VAZHUVADI
POPULATION PER 10 PITS
APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR APR. MAY JUN. JUL. AUG.
PERIOD

the period of high population was observed from the second half of June to the first half of August at Thazhakkara and from early June to the end of August at Vazhuvadi. In 1980 higher population was observed from the beginning of June to the end of August and Thazhakkara, while at Vazhuvadi it was observed from the beginning of May to the end of July.

The eggs were generally seen from the second half of May to the end of August. At both the locations eggs were not obtained during the second half of May in 1979 and during that year at Vazhuvadi eggs were obtained till the end of September.

First instar grubs were obtained from the second half of May to the beginning of October during 1978 at both the locations and from the beginning of June to the beginning of October in 1979.

At Thazhakkara second instar grubs were found from the second half of July to the first half of November during 1978 and first half of July to the second half of November in 1979. At Vazhuvadi in 1978 second instar grubs occurred from the first half of July to the first half of November and in 1979 they were observed from the first half of August to the first half of November only.

Third instar grubs were generally seen from the first half of October at both the locations (at Vazhuvadi from second half of October during 1977-78), to second half of June. However, grubs were seen up to the first half of July during 1977-78 at Thazhakkara and up to the end of July during 1978-79 at Vazhuvadi. During 1977-78 at Vazhuvadi grubs occurred only from the second half of October. Thus the grubs were in field for about 10 months.

Pupae were found from the first half of May during 1978 at both the locations, to the second half of July at Thazhakkara and the first half of July at Vazhuvadi. During 1979 at Thazhakkara pupae were seen from the beginning of April to the end of August and during 1980 also they were seen from the beginning of April, but only up to the end of July. At Vazhuvadi they were seen during the last two years from the first half of March to the end of July. Pupae were seen in all the observations during May to the first half of June.

3.5 Adult emergence of L. coneophora

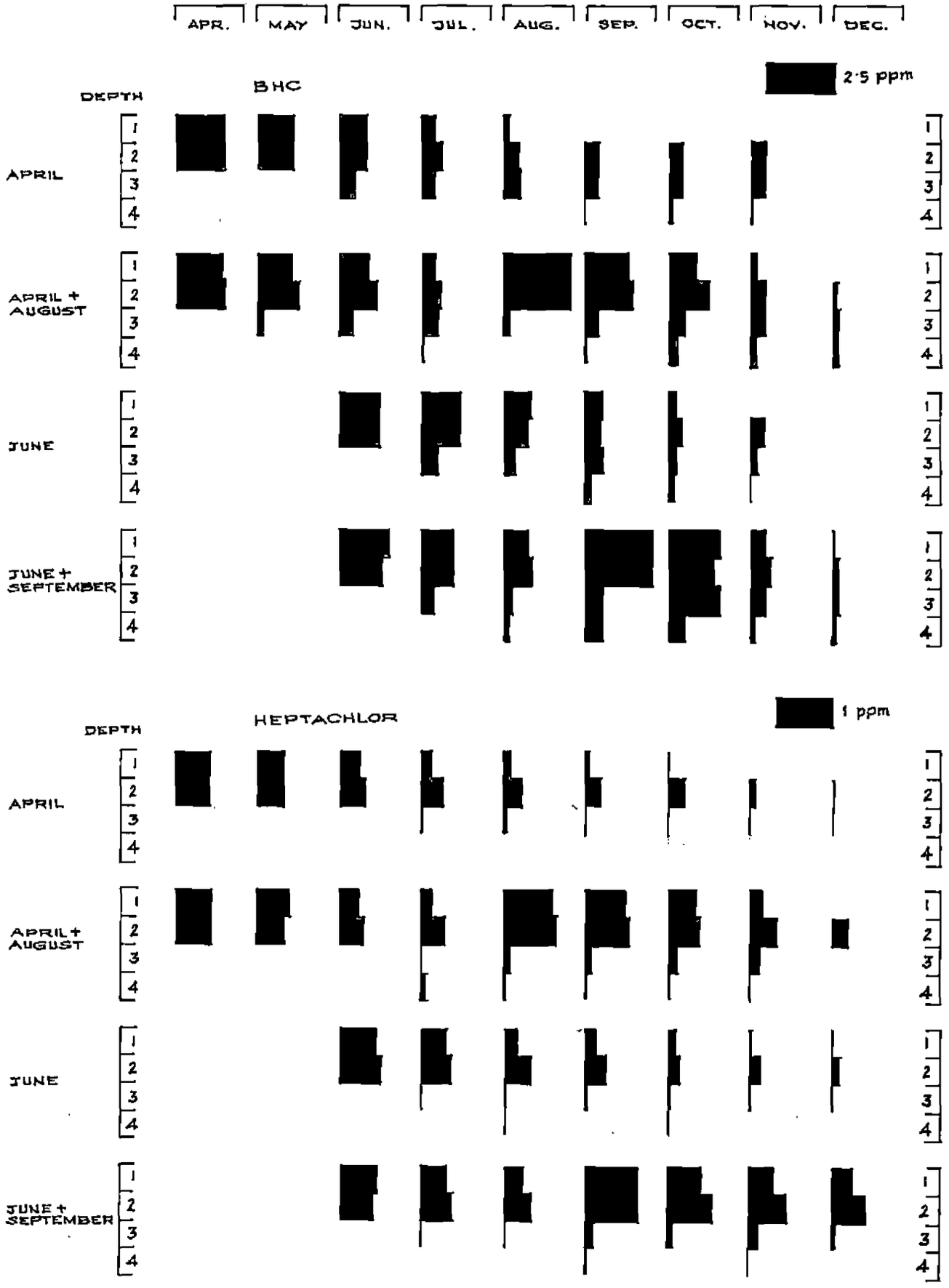
The number of beetles collected per week, from a 50 m^2 plot in an infested area, during 1976-78 is presented in Table 18 and Fig. 12 along with the average soil temperature and rainfall data of the corresponding

Table 18. Effect of rainfall and soil temperature on the adult emergence of L. concophora.

month & date	1976 rainfall (mm)	1976 Soil temp. °C	1976 No. of beetles	1977 rainfall (mm)	1977 soil temp. °C	1977 No. of beetles	1978 rainfall (mm)	1978 soil temp. °C	1978 No. of beetles
Mar. 7				0.0	38.0	0	12.3	37.7	0
14				13.6	36.5	1	0.0	37.4	0
21				21.6	36.2	2	16.1	35.5	2
28				0.0	37.5	0	12.8	37.5	0
Apr. 4	10.0	36.5	0	0.0	37.0	0	10.6	37.5	0
11	5.0	36.0	5	3.6	36.4	7	41.9	35.7	12
18	15.0	36.4	33	3.6	36.1	10	0.0	37.0	0
25	7.0	36.3	25	31.9	36.2	10	30.3	34.2	5
May 2	0.0	36.0	2	14.8	36.1	4	7.4	36.2	6
9	0.0	37.0	0	113.6	33.0	4	57.5	35.3	11
16	0.0	37.4	0	75.3	32.0	11	62.2	35.0	30
23	40.0	35.2	1	26.4	33.8	28	168.3	31.5	32
30	12.5	35.0	2	101.4	32.1	35	75.9	33.1	29
Jun. 6	152.0	34.6	19	62.7	30.5	50	119.3	28.9	48
13	29.0	35.3	22	119.8	31.5	75	100.8	31.9	40
20	0.0	36.3	32	164.5	27.6	102	110.0	29.7	84
27	85.0	33.2	51	103.7	28.1	241	141.6	31.7	123
Jul. 4	60.0	30.2	90	17.9	30.2	460	42.4	30.2	179
11	40.0	30.7	81	73.6	29.4	389	169.8	28.9	75
18	33.0	29.9	70	136.3	29.5	117	23.2	29.0	268
25	68.0	29.1	82	142.8	27.2	80	191.9	29.1	128
Aug. 1	78.2	30.9	82	3.3	29.5	33	92.0	28.0	26
8	110.1	31.0	25	0.8	33.5	4	90.3	29.3	9
15	7.0	33.0	4	38.2	31.9	0	71.0	28.7	4
22	140.0	33.5	0	83.7	30.7	0	134.2	28.6	0
29	21.2	32.5	0	81.9	30.1	0	0.0	30.5	0
Sep. 5	1.2	28.1	0	17.0	30.5	0	0.0	31.9	0
12	5.6	32.1	1	70.6	30.4	2	1.6	34.4	0

Fig. 12. Adult emergence of L. ooneophora in relation to rainfall and soil temperature.

FIG. 13.


APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
BHC
2·5 ppm
DEPTH
APRIL
APRIL + AUGUST
JUNE
JUNE + SEPTEMBER
HEPTACHLOR
1 ppm
1 = 0-7·5 cm. 2 = 7·5-15 cm. 3 = 15-30 cm. 4 = 30-45 cm.

treatment was 66.4 and 35 days, respectively. The quantity of insecticides found in samples as per chemical and bioassay were showing an overall agreement. The half life of BHC when applied in April as estimated by the two techniques was 89.6 and 97.6 days, respectively. For the June, August and September schedules half lives as estimated by chemical assay were 71.8, 66.4 and 35 days, respectively, while the corresponding values for bioassay were 74.00, 64.3 and 37 days.

The downward movement of BHC applied in April commenced significantly with the onset of monsoon in June and in subsequent observations 20.3 to 50 per cent of the total residue available was observed in the layer 15-30 cm depth. Movement of residue to the lower layer of 30-45 cm depth was observed during the fifth and sixth months after treatment and the residues present in these layers were 3.7 and 1.9 per cent of the total residues, respectively. When applied in June higher proportion of the pesticide had moved to the lower depths. Residues ranging from 13.6 to 50 per cent of the total quantity were found at the depth of 15-30 cm and 6.6 to 23 per cent at the depth of 30-45 cm. In the case of August and September treatments also higher movement of the insecticide to the lower depth of 30-45 cm was observed.

The data relating to the persistence and movement of heptachlor are presented in Table 22 and Fig. 13. The persistence of heptachlor was found to be more than that of BHC. The half lives of the pesticide applied in April, June, August and September were 72.2, 76.5, 87.7 and 82.3 days, respectively. When applied in April the pesticide moved to the third depth of 15-30 cm only and the residue from 1.63 to 16.6 per cent of the total quantity available in the soil had moved to this layer. The insecticide was not detected in soil of lower depths. But in June application, 4.2 per cent was observed in the fourth depth in the month of October. In August application, residue ranging from 4.76 to 29.4 per cent of the total quantity was detected in depths of 30-45 cm. In general the movements in terms of distance and quantity were less than that of BHC.

Table 22. Persistence and downward movement of heptachlor applied on surface layer of loamy sand soil.

treatments	soil depth (cm)	insecticide residue (ppm) in soil observed in the month of									half life period (days)
		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Bioassay											
Heptachlor 5 kg ai/ha applied in April	0- 7.5	0.68*	0.50	0.40	0.20	0.01	0.05	0.01	0.00	0.00	
	7.5- 15	0.70	0.50	0.45	0.40	0.35	0.30	0.31	0.10	0.05	
	15 - 30	0.00	0.00	0.00	0.01	0.05	0.00	0.01	0.01	0.01	
	30 - 45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	mean	0.36	0.25	0.21	0.15	0.12	0.09	0.08	0.03	0.01	72.2
Heptachlor 5 kg ai/ha each applied in April and August	0 -7.5	0.70*	0.61	0.39	0.21	0.90*	0.73	0.55	0.20	0.00	
	7.5- 15	0.69	0.58	0.42	0.43	0.95	0.80	0.60	0.50	0.30	
	15 - 30	0.00	0.00	0.00	0.01	0.08	0.10	0.15	0.15	0.00	
	30 - 45	0.00	0.00	0.00	0.05	0.03	0.04	0.04	0.01	0.00	
	mean	0.34	0.28	0.20	0.17	0.49	0.41	0.33	0.21	0.07	76.5
Heptachlor 5 kg ai/ha applied in June	0 -7.5			0.70*	0.52	0.30	0.18	0.15	0.08	0.02	
	7.5- 15			0.72	0.58	0.48	0.36	0.23	0.20	0.13	
	15 - 30			0.00	0.01	0.05	0.08	0.07	0.05	0.03	
	30 - 45			0.00	0.00	0.00	0.00	0.02	0.00	0.00	
	mean			0.35	0.28	0.21	0.15	0.12	0.08	0.05	87.7
Heptachlor 5 kg ai/ha each applied in June and September	0 -7.5			0.71*	0.55	0.40	1.01	0.63	0.42	0.40	
	7.5- 15			0.68	0.60	0.52	1.05	0.81	0.70	0.62	
	15 - 30			0.00	0.02	0.02	0.15	0.10	0.15	0.09	
	30 - 45			0.00	0.00	0.00	0.02	0.00	0.01	0.00	
	mean			0.34	0.29	0.24	0.55	0.38	0.32	0.27	82.3

*Residues in samples collected 24 hours after insectioidal application.
Weather data has been given in Table 21.

DISCUSSION

D I S C U S S I O N

The biology of Leucopholis coneophora Burm. was studied in detail for the first time, though brief descriptions of the life stages of the pest were published by Nirula et al. (1952), Nirula (1958), Sekhar (1958) and Veeresh et al. (1982). The eggs were seen deposited singly in moist earthen cells. The cells were formed by the extrusion of the vagina, preceding the laying of each egg. It could not be confirmed whether the extruding vagina produced the cell by mere compaction of the soil or whether any cementing substance also was secreted by the insect. Formation of such cells was not reported earlier on L. coneophora. Tashiro et al. (1969), Fleming (1972), Veeresh (1977) and Yadava (1981) had observed similar egg chambers in soil made by A. majalis, P. japonica, H. serrata and H. consanguinea, respectively. Tashiro et al. (1969) and Yadava (1981) also found that the formation of egg chamber was by extrusion of the vagina which formed a bulbous organ.

The eggs of L. coneophora were observed to increase in length and width from the third to the ninth day of incubation and subsequently the size remained static. Nirula (1958) also had observed a similar increase in the size of the eggs of L. coneophora. But he took the

measurements of eggs immediately after egg laying and just before hatching only. No other reference relating to the increase in size of the eggs of L. ooneophora in early development was seen in literature. But similar increase in the length and width of eggs was reported on A. majalis (Schwardt and Whitcomb, 1943), H. longipennis (Haq, 1962) and H. serrata (Veeresh, 1977).

It was observed in the present investigation that the weight of the egg also increased from third to the fifteenth day. The increase in size and weight followed a sigmoid trend. Increase in weight was reported for the eggs of M. melolontha (Hurpin, 1956 b) and Costelytra zealandica White, the grass grub of New Zealand (Wightman, 1973). The absorption of moisture during developmental phase of the egg was attributed as the reason for the increase in size. Fleming (1972) found that newly laid eggs of P. japonica contained 45-50 per cent of water, whereas the water content was 81.8 - 84 per cent at hatching. He observed that this higher percentage of water content could fully account for the increase in weight during embryonic development.

Morphology of the first, second and third instar grubs was studied in detail with a view to fixing

distinct identifying features for various instars. As it is obvious from the results presented the three instars of grubs could be distinguished by the difference in head capsule width and body size only. Mean head capsule widths of the first, second and third instar grubs were 3.19, 4.84 and 7.71 mm, respectively. These differences could easily be made out by visual observations also. In the present study the body length, width, weight and head capsule measurements as well as the duration of development were studied separately for the grubs destined to develop as males and females. The results showed that there was no significant difference in the size and head capsule measurements of the first and second instar grubs of the male and female insects. But in the third instar stage, the male grubs were significantly shorter and weighed just half that of females. Sekhar (1958) and Nirula (1958) had given a brief description of the first and third instar grubs of L. conocephora collected from the field. The measurements reported by these authors showed slight variation from those of the present studies. The difference in weight seen between the grubs of the two sexes could be due to the increase in development of the reproductive system and higher storage of fat bodies in females. With reference to the size

and weight of pupae and adults also the same trend between males and females was observed. In the larval duration no major difference was noticeable.

In earlier descriptions of the adults of L. coneophora, Nirula (1958) alone had attempted to differentiate the two sexes on morphological characters. He had pointed out the difference in shape of the tibial spur of the hindlegs as a reliable character for differentiating the sexes. But this character was found confusing in the field observations and hence a more reliable morphological character was sought in the present investigation. In the case of L. irrorata (Lopez, 1931 b) and A. majalis (Tashiro et al., 1969) antennal characters was pointed out as a means of separating the sexes. Hence that character was studied for L. coneophora and it was observed that sexes could easily be separated on the basis of size of the antennal club. The antennal club of the males was 2.55 mm long and thrice as long as its width, whereas in the case of females it was 1.62 mm long and twice as long as its width.

Adult behaviour of L. coneophora was observed in detail in the present investigation. The emerging males left distinct emergence holes in the soil (Plate III) which gave an indication of the population level of the pest during the period of observation. The existence

of such emergence holes and their significance in estimating the possible crop damage in succeeding months was pointed out with reference to H. serrata (Veeresh, 1977). The beetle emerging out of the soil remained on their wings for a shortwhile. They remained above soil for 25-35 minutes only. The emerging individuals were predominantly males. The sex ratio of the beetles collected from field was 1 : 0.099 (males : females) whereas in laboratory rearings the proportion observed was 1 : 0.734. The males alighting on the ground located the females remaining in soil with their antennae protruding out. Soon the females were seen coming out of the soil and mating the with the males. Immediately after the commencement of the mating the male was dragged into the soil by the female, the mating process being continued. Mating process was typical of other melolonthine beetles (described by Veeresh, 1977 and Yadava, 1981). Nirula (1958) reported that the mating could be observed in the leaf-stalks of adjacent plants too. But in the course of the present investigation such behaviour was not noticed.

The adult feeding of L. coneophora was studied for assessing the possible damage to intercrops in the infested coconut gardens. The plants available in the

locality were provided in laboratory for feeding. There was no indication of feeding on any of the materials provided. The gut content of the field collected beetles also indicated that the adults did not feed on any vegetation. Lack of feeding in the adult stage of L. coneophora was reported earlier by Sekhar (1958), Nirula (1958) and Veeresh et al. (1982). But other species of the genus, L. rorida(Leefmans, 1915), L. pinguis (Beeson, 1921) and L. irrorata (Otanes and Karganilla, 1940) were reported to feed on the foliage of crop plants as well as weeds in the vicinity. The practice of collecting and destroying the beetles of some root grubs like H. serrata and H. consanguinea, while congregating on food plants in the site of emergence, was not found feasible in the case of L. coneophora.

Among the different species of Leucopholis, L. coneophora was found widely distributed in Kerala. L. burmeisteri had also been reported from the northern districts of the State. These species and L. lepidophora were reported from different districts of Karnataka too. Separation of the grubs of these species on morphological characters will have relevance in pursuing scientific investigations on the bionomics

and control of these pests. Veeresh (1981) and Veeresh *et al.* (1982) studied important characters of *L. lepidophora* and *L. burmeisteri* and some salient characters of *L. coneophora* for the purpose of identifying the grubs of the three species. Since it was not sufficiently comprehensive a detailed study of the morphological characters of *L. coneophora* was made and by utilising the description of *L. lepidophora* and *L. burmeisteri* given by Veeresh (1981) a key was developed for the identification of the grubs of these three species.

The number of antero-frontal setae and pali were found to be lower than the range reported by Veeresh *et al.* (1982) and in the case of stridulatory teeth it was observed to be higher than the range reported. There was general agreement with reference to the other characters studied.

As in the case of any other insect, the root grubs were also influenced by the type of food they received during the period of development and that factor affected the survival rate in development and subsequent build up of the population. This phenomenon was observed on *Aphodites howitti* Hope (Crane, 1956), *H. consanguinea* (Kalra and Kulshreshtha, 1961), *C. zealandica* (Farrell and Sweney, 1974) and

M. melolontha (Hauss, 1975). In order to ascertain the influence of various inter or mixed crops grown in coconut gardens in the root grub-infested tracts in Kerala the effect of four representative crops viz. cassava (for tuber crops), coconut (palms), cacao (tree crop) and wild sunn-hemp (legume) on the development and biology of L. coneophora was studied. The results presented revealed that the different host plants tested had significant influence on the development and population build up of the insect. In terms of the duration of development from egg to adult, cassava was found to be the best host for females of L. coneophora and cassava and coconut were on par and superior to other host plants in the case of males. Cacao and crotalaria were on par though the duration was the longest in the latter host. Influence of nutrition on the larval duration among root grubs was observed earlier on A. howitti (Crane, 1956) and H. consanguinea (Kalra and Kulshreshtha, 1961). The duration of development of first instar stage was not significantly varying. The favourable influence of nutrition was manifested in the second instar stage and persisted throughout the remaining stages of development. The size, as manifested by length and width of third instar grubs also showed favourable influence of cassava and coconut.

In general, crotalaria was the least favourable and cacao came in between. Kalra and Kulshrestha (1961) found that grubs of H. consanguinea fed on sugarcane had greater length and width than those fed on grass roots. With reference to weight gain, the different hosts had no influence in the case of male grubs, while cassava and coconut were found to be better host plants for female grubs. In the case of body size and weight of adults also the same favourable trend of coconut and cassava was distinctly manifested. In general, cacao and crotalaria were on par and inferior to other hosts. Reports of weight difference based on larval food are available on other white grubs also. Weight gain of grubs of C. zealandica was significantly different on Lotus pedunculatus than on a hybrid of this species (Farrell and Sweney, 1974). Greater overall weight increase in M. melolontha was recorded on broad leaved plants (Hauss and Schutte, 1976).

The influence of different hosts on survival of immature stages of L. coneophora was revealed in Table 5 and Fig. 3. It was also observed that the difference in the survival percentage got manifested in the pupal and adult stages only. Population build up is likely to take place much faster when fed on cassava

and oocconut roots than on cacao and crotalaria. Hauss and Schutte (1976) observed that the mortality of M. melolontha was less for grubs fed on broad leaved plants than on roots of grasses. They also found that the effect of food on mortality and weight gain was not apparent until the grubs reached second instar stage. Wilson (1978) reported that survival of C. zealandica was highest on large leaved vigorous lines of white clover. With regard to the longevity of males of L. coneophora also cassava and coconut were on par and significantly superior to the other two crops. But in the case of females cassava was superior even to coconut. Similarly, the adults reared using cassava and oooonut had significantly longer preoviposition period and higher fecundity as compared to the adults reared on cacao and crotalaria. Initial body weights of female adults reared on cassava and coconut were significantly higher than that of females obtained from other crops. Higher egg production was also seen in females having higher initial body weight. The eggs laid by them showed a higher hatching percentage also. Farrell (1973) reported that egg produotion of C. zealandica varied significantly with initial body weight. These results indicated the possibility of some favourable factors in the nutrient content of cassava and coconut

which increased the biotic potency and survival rate of L. coneophora. In general different hosts seemed to have same influence on the grubs of males and females of L. coneophora. Tho overall result obtained from these studies indicated the possibility of a higher population build up of L. coneophora in coconut gardens with no intercrops and those cultivated with cassava than in gardens inter/mixed cropped with cacao or crotalaria.

The nature and extent of damage caused by L. coneophora on the inter/mixed crops referred to earlier were also studied in detail. Cassava was found to be highly susceptible to the infestation of L. coneophora at the time of planting and during the early stages of growth. The grubs ate away the roots and rind of the stem just below the ground level which resulted in the failure of absorption and translocation of nutrients and water from the soil. As a result of this the aerial portions of plants got stunted and they gradually died. The death of the plant was hastened as a result of moisture stress. Normally the planting of cassava was usually being done during the summer showers of March and April, when the third instar grubs of L. coneophora remain active.

As a result of this, a prophylactic treatment with insecticides had become an inevitable practice for getting proper establishment of the crop in the pest infested tracts in Kerala.

The injury done to cassava in later stages of growth was relatively lower as revealed from the second experiment. Even with a population level of five grubs per plant, none of the plants died out completely. With reference to the various growth characters the incidence of the pest was found to affect the plants adversely to a significant level even with a lower population of one grub per plant. The damage done by the population level of one grub per plant did not vary significantly from the next higher level of three grubs per plant. These were on par with five grubs per plant level of population with reference to the number of newly emerging leaves and weight of roots other than tubers. With regard to the remaining effects studied the population level of five grubs per plant was significantly more deleterious. The grubs getting access to a well formed tuber kept feeding on it without damaging nontuber forming roots or the remaining healthy tubers. This probably kept the plant apparently healthy though a significant reduction in the yield of healthy tubers was brought about.

The results obtained from the experiment revealed that limited numbers of tubers in a plant alone were damaged due to the infestation of L. coneophora grubs and even in infested tubers the damage was partial. Hence it was found desirable to assess the reduction in quality of the undamaged tubers and of the partly damaged tubers in infested plants and also their consumability. The data presented in Table 7 showed that the quality of undamaged tubers in the plants infested by the grubs, in terms of starch, amylose, amylopectin and hydrocyanic acid content remained on par with tubers of the plants unexposed to the grubs. But the unaffected portions of partly damaged tubers showed a lower percentage of starch and amylose and a higher percentage of amylopectin. In the infested tubers the HCN content was relatively lower. The mechanical injury caused by the grubs could have facilitated the escape of HCN from the tubers. The reduction of total starch and amylose and increase of amylopectin would reduce the cooking quality of the tubers. The taste panel also reported them to be less acceptable for consumption.

The data given in Table 8 and Fig. 6 showed that cacao was highly susceptible to damage by L. coneophora. Even at the population level of one grub per plant, at four-month-old stage, the emergence of new leaves and

growth of the plant got significantly reduced. The absence of new flushes led to a stunting in the plant, reduction in the underground and top growths.

In the case of crotalaria also the population level exceeding one grub per plant was fatal. Even with one grub per plant, crotalaria was seen badly affected. Significant reduction in growth was observed even in plants with intact tap roots. This might have been cuased by the feeding injury on the side roots and rootlets.

Being a perennial plant the effect of different levels of grub population on coconut could not be studied in potculture experiment. The symptoms of damage due to the infestation of L. coneophora on coconut palms in field also were difficult to notice in the beginning of infestation. But palms in the gardens reported infested since 1952 showed the clear symptoms of infestation such as the reduction of roots, shortening of leaves, yellowing of leaflets and shedding of buttons and immature nuts. Consequently the yield was drastically reduced. Similar observations were made on infested palms by Veeresh and Viswanath (1983) in Karnataka.

Data in Table 10 and Fig. 8 showed that a higher percentage of beetle population of L. coneophora remained

at 30-100 cm, the maximum population being confined to a range of 60-100 cm depth. Beetles collected till the month of June were mostly from the depths of 45-100 cm whereas a relatively higher proportion was obtained at 15-30 cm depths from June to August. The beetles collected till June might have been pre-emergence individuals whereas the collection obtained from July onwards included the beetles which had emerged, mated and resettled for egg laying. Since the eggs were usually laid in upper strata of the soil, the mated beetles would have preferred the upper zones. Rai et al. (1969) also recorded a similar phenomenon in H. consanguinea, where the beetles found at a depth of 75 cm before emergence resettling in a depth range of 0-30 cm after emergence.

With reference to the distribution of eggs the least number was found in the range of 0-15 cm depth. The distribution of the eggs in lower depths over different years showed an erratic trend. In general, a higher proportion of eggs was found in the depth range of 15-60 cm. At both the locations a higher percentage of eggs was observed in depths of 60-100 cm during May and June. From the month of July to September they were largely obtained from the range of 15-60 cm depth. Nirula (1958) observed that the eggs were laid at 7.5 - 15 cm

normally while in summer they were found up to a depth of 30 cm. But in the present investigation 30 cm depth was found to be the normal and preferred zone. Beetles of majority of root grubs lay eggs in upper layers reaching a depth of 15 cm (Haq, 1962; Srivastava and Khan, 1963; Raodeo and Deshpande, 1981; Nair and Daniel, 1982). But in the case of L. rorida (Leefmans, 1915), L. irrorata (Otanes and Karganilla, 1947) and H. insularis (Srivastava and Khan, 1963) deeper depths were also seen preferred for egg laying. The distribution of eggs might be in relation to the nature of the roots available in different depths for the feeding of grubs. Eighty per cent of the coconut roots were reported to be found below a depth of 30 cm in loamy sand soils (Kushwah et al., 1973) and this might have caused the preference of L. coneophora for deeper strata of soil during egg laying.

The highest population of first instar grubs was seen at a depth range of 15-30 cm during 1978 and 1979 at both the locations. Percentage of population in the depth range of 0-15 and 30-45 cm was rather erratic for two centres and also during the two years of observation. Though the eggs were seen in deeper layers, first instar grubs were seen in fairly large numbers in the upper strata of 15-30 cm, where the

cocconut roots normally do not exist. Obviously, the first instars depended on the roots of weeds and other intercrops as source of food. Nirula (1958) and Veeresh et al. (1982) observed that first instar grubs largely depended on organic matter and the roots of grasses and weeds for their feeding.

Second instar grubs were largely distributed at 15-45 cm depths. Percentage of grubs seen at lower depths was very low. Generally, the top zone of 0-15 cm also had less population though at Thazhakkara during 1979, 24.4 per cent of the population was recorded in that zone. Between the two depths of 15-30 and 30-45 cm slight preference for the former depth range was indicated but this did not hold good for both the locations and for the entire period of observation. In the different months during the period of observation no definite trend in the depth-wise distribution of grubs could be made out.

Regarding the third instar grubs the highest population was observed at a depth of 15-30 cm during 1977-78 and 1978-79 at both the locations. During 1979-80 at both the locations the maximum population was at 45-60 cm depth. During 1979-80 the total rainfall was just half that of the other two years, especially from October to May. Consequently the moisture

in the upper layers would have been lower during the period and temperature higher and that might have resulted in the preference of the grubs for deeper depths of soil. During the month of October, they were predominantly seen at 30 cm depth. When the rain was received in November the grubs even migrated to the upper strata of 15-30 cm. The influence of rain over the distribution of third instar grubs was also evident from the reverse trend in distribution from January. In January, February and March, the higher percentage of grub population was observed in deeper depths of 30-100 cm. This might be due to the comparatively higher soil temperature and less moisture in upper depths of soil during the summer months. Downward migration of grubs of L. coneophora from the upper to the lower layers during summer months was reported earlier also (Mathen et al., 1964 and Nirula, 1958). Holotrichia longipennis (Haq, 1962), A. majalis (Tashiro et al., 1969), P. japonica (Fleming, 1972), H. serrata (Veeresh, 1977) and H. consanguinea (Yadava, 1981) also were reported to move to different depths due to the fluctuations in moisture level.

Pupae were observed largely in the depths of 30-100 cm. The instances of pupal population observed in the higher level of 15-30 cm were mostly in the months of June and July, when the rainfall was high. The higher rainfall

stimulated the pupating grubs to remain up by virtue of the higher humidity conditions there. The depth chosen for pupation was identified as a species character (Ritcher, 1958). But Yadava (1981) observed that in the case of H. consanguinea soil temperature and moisture had considerable influence in deciding the depth of pupation. In the case of L. coneophora also it appeared to be influenced by the soil conditions.

The grouping of the number of adult and larval instars of L. coneophora with reference to different ranges of soil temperature and soil moisture (Fig. 9 and 10) indicated their strong tendency to congregate more in preferred zones of temperature and moisture. The adults preferred a temperature of 29-31°C and the soil moisture of 9-11 per cent. The first instar grubs were more predominant in a temperature range of 29-31°C while the second and third instar grubs preferred a temperature range of 31-33°C. The first, second and third instar grubs preferred 8-10, 8-10 and 7-9 per cent of soil moisture, respectively. Influence of soil moisture in the distribution of white grubs at different depths of soil was observed by earlier workers also. Nirula (1958) found that the grubs of L. coneophora remained in the superficial strata in the rainy season and migrated to deeper strata during summer season,

searching for zones with sufficient moisture. Venkitaramaiah (1969) observed the grubs of H. nilgiria stopping activity when the soil moisture went below 20 per cent. Rai et al. (1969) found that the grubs of H. consanguinea which normally remained at 15 cm depth moved to deeper layers of soil when drying occurred. Veeresh (1977) reported an upward and downward movement of grubs of H. serrata depending on the soil moisture. Shorey and Gyrisco (1960) observed that the grubs of A. majalis showed a preference for different ranges of soil moisture. But below the level of four per cent and above that level up to 12 per cent the grubs did not show any dominant choice. The movement of grubs in relation to the different levels of soil temperature has been reported in the case of H. longipennis (Haq, 1962), H. consanguinea (Rai et al., 1969), A. majalis (Tashiro et al., 1969) P. japonica (Fleming, 1972), M. hippocastani (Mischenko, 1974), H. serrata (Veeresh, 1977) and M. melolontha (Valenta and Gavells, 1979). Detailed studies conduoted for finding the different ranges of temperature and moisture preferred by any species of white grub were not seen in earlier literature.

The seasonal occurrence of the life stages of L. concophora also has been studied for the first time.

Period of occurrence of adult stage in the soil was found to be from the second half of May to the end of August. The commencement of the continuous emergence of adults coincided with the onset of monsoon with heavy rainfall. The delayed monsoon in 1979 had delayed the appearance of adults up to the beginning of June. However, at Vazhuvadi stray beetles were collected in April before the commencement of monsoon in May. So also, stray beetles could be collected rarely in September from both the centres. Since beetles were not found in the soil prior to the onset of monsoon it could be inferred that the delay in the occurrence of rain might have delayed the emergence of adults from pupae. With reference to the occurrence of beetle population in soil no distinct peak could be observed. In general the population in the months of June and July was higher than the population in May and August.

The period of occurrence of eggs had an overall agreement with the occurrence of adults in soil. In 1978 and 1980 the eggs were obtained from the second half of May, whereas in 1979 eggs were recorded from June onwards. Though at Vazhuvadi the beetles were recorded in the months of April and May the eggs were obtained in the samples collected from the latter half of May only. As seen from the mean number of eggs

presented in Table 16 there was no distinct peak period of occurrence of eggs in the field.

The first instar grubs occurred from the second half of May to the beginning of October, but the higher level of population was recorded from the second half of June to the end of September.

The second instar grubs, in both the locations occurred in significantly higher numbers from the second half of July to the first half of November.

The third instar grubs were seen from the first half of October to the end of July of succeeding year. The populations at both the locations were significantly higher from the second half of October to the first half of June, as compared to the populations in the preceding and succeeding periods. Populations recorded from different locations over a period of three years or the mean values did not reveal any distinct peak period of occurrence of third instar grubs in the field.

Pupae were seen from the beginning of March till the end of August, but the number recorded in March and August was relatively low and the regular period of occurrence of pupal instar can be treated as April to July.

Nirula (1958) had observed that eggs were seen from the middle of June to the end of August and that the grubs survived up to May. But in the present study the first instar grubs were seen up to the end of September and the third instar up to the end of July of the succeeding year. The seasonal occurrence of the different life stages of L. coneophora has significant bearing on the development of proper insectioide schedules for the control of the pest.

Period of commencement of peak emergence of adults was observed to fluctuate between the second week of May and the first week of June. The emergence declined by the last week of July or the first week of August. The total rainfall during the premonsoon period of March and April appeared to influence the time of peak emergence. In 1976, when the premonsoon rainfall was low the commencement of peak emergence was seen in June only. In 1978, when the maximum premonsoon showers occurred the emergence commenced by the first week of May. In 1977, the premonsoon rainfall was of an intermediate level and the emergence of adults commenced by the second week of May. Thus, it appeared that the total quantum of rainfall received in the months of March-April and early May rather than the commencement of rainy season initiated beetle emergence. Nirula (1958) opined

that first en masse emergence of beetles of L. coneophora started a fortnight after the commencement of the south west monsoon. Veeresh et al. (1982) observed that since pupating Leucopholis grubs go deeper compared to other species, sometimes reaching 60-70 cm, substantial precipitation is necessary for the moisture to reach this depth to trigger beetle emergence.

The soil temperature appeared to influence the emergence of beetles. The period during which it touched the mark of 37°C no beetle emergence could be observed. But such high levels of soil temperature occurred during the premonsoon period only and hence the adverse effect of high level temperature during the peak emergence period could not be observed during the period of this study. About 60 per cent of the total beetle population emerging from the soil was in the month of July in all the three years.

The present recommendation for the control of L. coneophora is two applications of heptachlor, BHC, chlordane or aldrin once in April and another in August. This recommendation was based on the results of a limited number of field experiments, the results of which were not in full agreement or conclusive (Nirula and Menon, 1957; Nirula, 1958; Mathen et al., 1964; Johnson and Nair, 1966; Abraham and Kurian, 1970).

The high degree of heterogeneity in the distribution of grub population in the field is probably the major factor for the inconsistency of the results obtained in the experiments. The timing of pesticide application as observed by Veeresh et al. (1982) will be very vital for the effective control of the pest. The present practice of treating the field in April does not appear to be purposeful since the pest population available in the field during that period is mostly in the third instar grub stage which inhabits deeper layers of soil, where the pesticides are not likely to reach.

A series of precise experiments were hence carried out in the present studies with a view to finding the most effective and economic insecticide for the control of L. coneophora and to fix the most advantageous period for the application of the pesticide. Chlorinated insecticides alone were included in the studies since pesticides like phorate, carbaryl, carbofuran, quinalphos and thiodemeton (Abraham, 1979) and malathion (Mathen et al., 1964) were reported very ineffective and also because the application of systemic granules to a perennial oil and food crop like coconut may cause residue hazards. The high cost of granules is another limiting factor.

In one experiment the relative toxicity of aldrin, BHC, chlordane and heptachlor was assessed adopting precise bioassay technique. Against the second instar grubs aldrin was found to be the best, closely followed by heptachlor, whereas the third instar was more susceptible to heptachlor than aldrin, the former being 1.8 times more toxic than the latter. On cost basis also heptachlor had to be preferred to aldrin. Though heptachlor was much more toxic than BHC (about three times toxic) to the grubs of L. coneophora the latter also was found appreciably effective. Chlordane, however, was found far less toxic than the other insecticides and ineffective.

No previous work has been reported on the bioassay of pesticides against the grubs of L. coneophora. Heptachlor which was found as the best insecticide in the present experiments was rated on par with aldrin, BHC and chlordane against L. coneophora (Abraham and Kurian, 1970) and was reported to be inferior to BHC, aldrin and chlordane earlier (Mathen et al., 1964). It was found to give satisfactory control of L. burmeisteri (Rao and Bavappa, 1961; Rao, 1963), L. lepidophora (Rao, 1963), L. rorida (Rao, 1966) and L. irrorata (Apostol and Litsinger, 1976b). Against H. consanguinea Sharma and Shinde (1970b) and Srivastava et. al. (1971) got encouraging results, while Desai and Patel (1965)

and Rai *et al*. (1969) found the pesticide ineffective. Against *H. serrata* Kaul *et al*. (1966) reported that heptachlor was less toxic than dieldrin, aldrin, chlordane and toxaphane. Since the technique followed in the present investigation was more foolproof the results obtained now may be treated as reliable. Aldrin, though equally toxic to the second instar grubs, was inferior to heptachlor against the third instar grub. Moreover, the cost of aldrin required for treating one hectare of coconut garden, at LD_{90} level, was 1.5 times that of heptachlor when the pest occurred in the second instar grub stage and 2.6 times when the pest was in the third instar stage. In view of these facts, aldrin was not included in further studies for evolving a suitable chemical control schedule against *L. coneophora*. Chlordane which was 9.4 times less toxic to heptachlor against the second instar grub and 4.3 times less toxic to the third instar grub also was dropped from further studies.

BHC was found less toxic than aldrin and heptachlor to *L. coneophora*. This insecticide had been widely tested against root grubs. Nirula (1958), Mathen *et al*. (1964) and Abraham and Kurian (1970) found the pesticide effective against *L. coneophora* while Johnson and Nair (1966) reported the insecticide ineffective. Against

L. rorida (Edgar, 1958), L. lepidophora (Rao, 1963), L. irrorata (Apostol and Litsinger, 1976b) and L. burmeisteri (Kumar and Daniel, 1981), BHC had been recommended as an effective pesticide. Against H. consanguinea also negative (Gupta and Avasthy, 1957; Prasad and Thakur, 1959; Khanna et al., 1968; Rai et al., 1969; and David et al., 1976) and positive (Kalra and Kulshreshtha, 1961; Desai and Patel, 1965; Joshi et al., 1969; and Srivastava et al., 1971), results had been reported on the efficacy of BHC. Against H. serrata David and Kalra (1966) and Abraham and Rajendran (1978) reported effective control with BHC, while Kaul et al. (1966), David et al. (1976) and Jose and Kaul (1978) found it ineffective. Though BHC was less toxic than heptachlor and aldrin to L. concophora the toxicity appeared to be sufficiently high to cause adequate and economical control of the pest under field conditions. Thus,based on the results of the bioassay studies BHC and heptachlor were chosen on efficacy-cum-cost criteria for further evaluation under field condition.

BHC and heptachlor applied in the field tubs in different schedules showed that all the treatments reduced the population of second instar grubs effectively prior to their attaining the third instar or pupal stage.

The performance of heptachlor at LD_{90} levels was better than that of BHC at the same levels. Among the different schedules in which the pesticides were tried, June and September application of both the insecticides and June application of heptachlor eliminated the pest prior to the attainment of pupal instar, whereas in field tubs treated with BHC in the month of June alone 1.79 percentage of the grubs reached the pupal stage. The schedule of April and August treatment of the two insecticides was significantly inferior to the June and September combination. A single application of either of the insecticides in April alone gave unsatisfactory control though heptachlor was better than BHC. It can be concluded that L. coneophora can be best controlled by a single round of treatment with heptachlor at the rate of 1.4 kg ai/ha in the month of June or with BHC applied in June and September, each treatment being made at the rate of 5 kg ai/ha of the toxicant. Application of any pesticide in April is likely to be less effective since the present studies showed that the third instar grubs present in the field during the period were not amenable to control using the insecticides tested under normal field dosages. Further the grubs inhabit the deeper strata of soil in April and the insecticides applied in the top layer of soil at 0-15 cm may not reach down to the grubs.

Large scale use of chlorinated insecticides in soil may pose the residue problems since they are reported to persist for very long periods under field conditions. Hence the extent of such hazard and the movement of pesticide downwards through infiltration were studied in detail. The results (Table 21, 22 and Fig. 13) showed that BHC applied in the months of April, June, August and September had half lives of 89.6, 71.8, 66.4 and 35 days, respectively, and the residues almost completely disappeared within 7, 5, 4 and 3 months, respectively. The persistence of BHC under conditions prevailing in Kerala was far below the persistence reported from subtropical countries viz. 3 to 5 years (Edwards, 1966), 11 years (Lichtenstein et al., 1971) and one year (Knutson et al., 1971).

The dissipation of 70 to 95 per cent of the residue was reported from different parts of India within periods ranging from 3 to 16 months (Agnihothri et al., 1974 and 1977; Kavadia and Gupta, 1976 and Srivastava and Yadava, 1977). The variation in the persistence of the insecticides applied in different months of the year could not be correlated with the total rainfall, soil temperature and mean atmospheric temperature as is seen in Table 21. The data in the table and Fig. 13 also showed that neither the quantum

of residues estimated by chemical and bioassay techniques nor the half life calculated did vary significantly. This showed the reliability of bioassay technique in the assay of BHC. The dissipation of heptachlor (Table 22) did not show significant difference from the trend shown by BHC. The half life of the insecticide applied during different months of the year did not show as wide a variation as in the case of BHC. Like BHC for heptachlor also Wilkinson and Finlayson (1964) reported persistence for nine years and Stewart and Fox (1971) for 12 years. Other studies reported so far showed persistence for periods ranging from four months to twelve months only (Knutson et al., 1971; Guenzi et al., 1971; Harris and Sans, 1972 and Agnihothri, 1978). In general, heptachlor was little more persistent than BHC.

With reference to the downward movement of the pesticides in soil under conditions prevalent in Kerala, it was seen that BHC mixed with the soil up to a depth of 15 cm reached up to a depth of 45 cm within a month or two. In the case of heptachlor the infiltration was taking place a little slower. In both the cases the quantity of pesticide residues reaching the lower depths of 15 to 45 cm was far below the level of concentration required for causing mortality of L. coneophora grubs. (LD_{50} values for second and third instar grubs were

0.7423 kg ai/ha (0.35 ppm) and 2.677 kg ai/ha (1.27 ppm), respectively, in the case of heptachlor and 2.371 kg ai/ha (1.12 ppm) and 7.017 kg ai/ha (3.34 ppm), respectively in the case of BHC). This indicated the desirability of raking the insecticides to deeper layers of soil for better control of L. coneophora in coconut gardens. Similar leaching of BHC to lower layers of soil have been reported earlier also (Lichtenstein, 1958; Krzymanska and Mackiewicz, 1969; Gawaad et al., 1971 and Venkitaramaiah and Singh, 1972). But Agnihotri et al. (1977) could not recover heptachlor or BHC from any depth below the level to which it was raked into the soil. Knutson et al. (1971) and Stewart and Fox (1971) found the penetration of heptachlor to a depth of 30 cm and 25 cm, respectively. The rate of downward movement of pesticide could not be correlated with rainfall since in all the months during the period of observation there was significant rainfall.

SUMMARY

S U M M A R Y

The biology of the coconut cockchafer Leucopholis coneophora Burm. was studied in full for the first time. The techniques for rearing the pest in rooted coconut seeds planted in pots were standardised. Details of egg laying, formation of egg chambers in soil and the increase in the size of the eggs during the embryonic development were observed in detail. The development of the grub stages of males and females was followed up separately. The larval characters viz. the length, width and weight of the grubs and the duration of the different instars were studied. It was observed that the grubs of males and females did not vary significantly in the first and second instar stages. The third instar grubs and the pupae of the males had only half the weight of those of females though in size the difference was not that significant. The mean larval duration was 260 days for males and 270 days for females and the pupal durations were 25.3 and 25.7 days, respectively. The study on the general morphology of the three instars of grubs did not show remarkable difference facilitating their identification except the head capsule widths which were 3.19, 4.84 and 7.71 mm for the first, second and third instars, respectively.

For the differentiation of the males and females of L. coneophora in field, the external characters of the beetles were studied and the size of the antennal club was identified as an easy and reliable index for the purpose. The antennal club of male was 2.55 mm long and thrice as long as its width, while that of the female was 1.62 mm long and twice as long as the width.

Adult behaviour of L. coneophora was studied in the field. The beetles emerging for a short flight before mating were largely males, while females remained in the soil with their head and antennae protruding. Ratio of males and females collected from field was 1 : 0.099, while that of laboratory rearings was 1 : 0.734. Adults mated on the ground and never rested on plants around. Mating process was typical of the melolonthine beetles. Emerging beetles left a hole at the point of exit and these emergence holes gave an indication of population density during the season.

Adults of L. coneophora did not congregate on trees around the point of emergence or feed on them. Exposure to different plant materials in the laboratory and the examination of gut content of beetles collected from field indicated that they did not feed in the adult stage. This restricted the possibility of adopting mechanical control of the pest by the collection and destruction of adults during emergence time.

Studies on the detailed external morphology of the third instar grub enabled the development of a taxonomic key for identification of the grubs of the three species of Leucopholis prevalent in Kerala viz. L. coneophora, L. burmeisteri and L. lepidophora.

The effect of four different host plants viz. cassava, cacao and wild sunn-hemp (crotalaria) selected from among the inter/mixed crops grown in coconut plantations, and the main crop coconut on the biology of L. coneophora was studied. Coconut and cassava had a favourable effect on the insect with reference to the duration of development and size of the third instar grubs, pupae and adults. Crotalaria was the least favourable host plant and cacao remained at an intermediate level. In the case of males the weight was not influenced by the different hosts, while cassava and coconut produced female grubs weighing more. Crotalaria and cacao were on par and inferior in this regard. With reference to the survival percentage of immature stages also, cassava and coconut were more favourable to the pest. Insects reared on these hosts had greater longevity and higher fecundity too. The hatching percentage of eggs laid by insects reared in these hosts was also higher. In general, the effect of different hosts on the grubs of male and female insects did not show remarkable variations. Results indicated the possibility

of faster build up of the population of L. coneophora in coconut gardens free of other crops and in gardens grown with favourable crops like cassava than in areas where plants like cacao and wild sunn-hemp are grown as intercrops.

The nature and extent of damage caused by grubs of L. coneophora on the above selected crops also was studied by exposing plants raised in pots to different levels of larval population. Cassava was more susceptible at planting time and during early stages of crop growth since the infestation often caused the death of plants due to the eating up of the rind around the stem at ground level. In later stages, though the yield was reduced to some extent, plants were not totally killed even with a population of five grubs per plant. The edible quality of attacked tubers got reduced probably due to a fall in amylose content and increase in the fraction of amylopectin. But the unattacked tubers in infested plants were not affected. A taste panel also reported the poor quality of the apparently healthy portion of partly damaged tubers.

Cacao was found to be highly susceptible to L. coneophora. Even with the population of single grub per plant the total height and tap root length were drastically reduced and the production of new leaves

practically arrested. The weights of aerial and underground growths were also significantly reduced.

Crotalaria was most susceptible. A population level of one grub per plant significantly reduced the number of branches and leaves, length of roots and weight of above-ground and underground growths.

In cooonut seedlings the grubs tunnelling at the collar region caused the drying up of the spindle leaf followed by the yellowing of outer leaves and gradual death of the plants. Gardens infested by the grubs continuously for years caused debility of the palms, yellowing of leaves, shedding of buttons/immature nuts and consequent reduction in yield.

Population of different life stages of the pest in different depths of the soil was studied at two locations in the infested belt over a period of three years. The beetles were found more at depths of 30-100 cm during pre-emergence season and between 15 and 30 cm depths during post-emergence period. Eggs were seen predominantly at depths of 30-100 cm, first instar grubs at 15-30 cm, second instar at 15-45 cm and third instar at 15-30 cm. Lack of sufficient moisture in upper strata induced a downward movement of the grubs and that led to an erratic trend in their distribution during different periods

of the year. The pupal instars were more in deeper strata of 60-100 cm depth.

Grouping of the numbers of adult and three instars of grubs of L. coneophora over different ranges of temperature and moisture for the three years of observation revealed their tendency to prefer certain ranges of temperature and moisture. The adults preferred a soil temperature of 29-31°C and soil moisture of 9-11 per cent. First instar grubs preferred 29-31°C while second and third instar preferred 31-33°C. The soil moisture ranges preferred by the first, second and third instar grubs were 8-10, 8-10 and 7-9 per cent, respectively.

The seasonal occurrence of the life stages of L. coneophora also was studied for the first time over a period of three years. Adults were collected from May to August and the population was more in June and July than in other months. Eggs occurred from the latter fortnight of May to the end of August, first instar grubs from the second half of May to October, second instar from second half of July to first half of November and third instar was found from first half of October to the end of July of the succeeding year. Pupae were seen from the beginning of April to the end of July.

The adult emergence appeared to be triggered by the quantum of rainfall during the premonsoon period rather

than the commencement of the rainy season. During early emergence period in March/April when soil temperature reached 37°C the beetles failed to emerge. However, no correlation was observed between beetle emergence and factors like rainfall, soil moisture and soil temperature during May to August.

Since the results of insecticidal control experiments reported earlier were not conclusive probably due to the erratic nature of the distribution of the pest, the toxicity of four chlorinated hydrocarbon insecticides to the second and third instar grubs of L. coneophora was assessed by adopting precise bioassay techniques suitably developed for the purpose. The order of toxicity of the insecticides against the second instar grub was aldrin > heptachlor > BHC > chlordane and against third instar grubs it was heptachlor > aldrin > BHC > chlordane.

Based on the bioefficacy data and cost factor haptachlor and BHC were further evaluated in a field trial (in tubs) for the control of L. coneophora. Results revealed that one application of heptachlor at 1.4 kg ai/ha in June or two applications of BHC each at 5 kg ai/ha in June and September would give complete kill of grubs. Insecticide treatment in April was found to be less effective probably because the only life stage of the pest available in field during the period was third instar grubs which

lived in deeper strata of soil in April and which required a very heavy dose of pesticides to get killed. The germination percentage of groundnut seeds sown in treated tubs also endorsed the above findings.

Since the use of chlorinated hydrocarbon insecticides in soil is generally believed to leave residues for long periods and also because no previous studies in this line were available the persistence of BHC and heptachlor in Kerala soils was studied using standard chemical and bioassay techniques. The half lives of BHC applied during April, June, August and September were 89.6, 71.8, 66.4 and 35 days, respectively and for heptachlor the half lives varied from 72.2 to 87.7 days.

The downward movement of the pesticides was assessed to know the possibilities of the toxicant, normally raked to a depth of 15 cm in soil, reaching the lower strata where the life stages of the pest are generally seen in large numbers. BHC and heptachlor penetrated to a depth of 45 cm within a month or two after treatment but the quantity thus moving down was too low to cause the death of any of the grub stages of L. coneophora. This indicated the desirability of incorporating the insecticide to lower depths in soil.

REFERENCES

REFERENCES

Abbott, W.S. (1925). A method of computing the effectiveness of insecticides. J. econ. Ent. 18: 265-267.

Abraham, V.A. (1979). Investigations on cockchafer beetle Leucopholis coneophora Burm. Ann. Rep. Central Plant. Crops Res. Inst., Kasaragod. P. 276.

Abraham, V.A., and Kurian, C. (1970). Save your coconut palm from the raveges of white grubs. Cooon. Bull. 1: 3-4.

Abraham, V.A., and Rajendran, T.P. (1978). White grub infestation in Kerala. Whitegrubs Newsl. 2: 3-5.

Agnihotri, N.P. (1978). The degradation of pesticides in soil. In: Proc. Symp. on 'Pestioide residues in the environment in India' (Ed. Edwards et al.), UAS, Hebbal, 1978. pp.343-356.

Agnihotri, N.P., Pandey, S.Y., and Jain, H.K. (1974). Persistence of BHC and aldrin in soil and translocation in mung (Phaseolus aureus L.) and lobia (Vigna sinensis). Indian J. Ent. 36: 261-267.

Agnihotri, N.P., Pandey, S.Y., Jain, H.K., and Srivastava, K.P. (1977). Persistence of aldrin, dieldrin, lindane, heptachlor and p-p' DDT in soil. J. ent. Res. 1: 88-91.

Apostol, R.F., and Litsinger, J.A. (1976a). Low insecticide dosage for control of white grub Leucopholis irrorata in an upland rice corn cropping pattern. Paper presented at the Seventh National Conference of the pest control Council of the Philippines, Cagayan de Oro, May 5-7, 1976.

Apostol, R.F., and Litsinger, J.A. (1976b). White grub in upland and rice-corn cropping pattern. Int. Rice Res. Newsl. 1: 23.

Anonymous. (1968). Cookchafers. Planter's Bull. Rubb. Res. Inst., Malaya No. 97: 102-113.

Anonymous. (1976). Ann. Rep. Rubb. Res. Inst., Malaysia. 302 p.

A.O.A.C. (1965). Official and tentative methods of analysis. 10th Edn. Association of Official Agricultural Chemists, Washington, D.C. pp. 24. 100-105.

Avasthy, P.N. (1967). Sugarcane pests in India, their control - a review. PANS. 13: 111-117

Beeson, C.F.C. (1921). The food plants of Indian forest insects Part IV - Indian Forester 47: 247-257.

Bellotti, A., and Schoonhoven, A. Van. (1979). Miscellaneous pests of cassava. Cassava Programme. CIAT, Colombia. pp. 233-238.

Bhakatia, D.R.C., and Sukhija, H.S. (1978). Brief account of the research work on white grub in Punjab. Whitegrubs Newsl. 2: 18-19.

Bhatnagar, O.K., Gupta, M.N., and Vishwakarma, S.L. (1975). Efficacy of various pesticides against white grubs (Holotrichia serrata) of groundnut. Pesticides 9(10): 22-24.

Blanchard, E. (1845). Historie des Insects 1: 216.

Brenske, E. (1892). Beitrag zur kenntniss der Gattungen Lepidiota und Leucopholis. Berliner Entomology Zeitschri. 37: 33-61.

Brenske, E. (1894). Die melolonthiden der Palaeartischen und Orientalischen region im Koniglichen natur historischen Museum zu Brussel. Mem. Soc. Ent. Belg. 11: 31.

Burmeistor, Hermann. (1855). Handbuch der Entomologie. IV. 2. Bierter Band. Befondere Entomologie, Fortfebung. Berlin. P. 303.

Carter, F.L., and Stringer, C.A. (1970). Residues and degradation products of technical heptachlor in various soil types. J. econ. Ent. 63: 625-628.

Chacko, M.J., and Krishnamoorthy Bhat, P. (1974). Control trials with granular insecticides against cockchafer attacking coffee. Indian Coffee 38: 98-99.

Crane, P.B. (1956). An ecological study of the pasture Scrab Aphodius howitti Hope. Aust. J. Zool. 4: 259-314.

Couturier, A. (1967). Differential susceptibility of Melolontha melolontha as regards certain wave lengths of the visible spectrum. Ann. Soc. Ent. Fr. 3: 767-770.

Couturier, A., and Robert, P. (1956). Observations on Melolontha hippocastani F. Ann. Epiphyt. 7: 431-458.

Daniel, M., and Kumar, T.P. (1976). Pests of Arecanut. J. Plant. Crops 4: 68-77.

David, H., and Kalra, A.N. (1966). Observations on Holotrichia (=Lachnosterna) serrata F., a beetle pest of sugarcane in Hospet area of Mysore State. Indian Sugar 16: 195-198.

David, H., Ananthanarayana, K., Alexander, K.C., and Ethirajan, A.S. (1976). Integrated control of white grub Holotrichia serrata F. on sugarcane. Symp. on Plant. Prot. Res. & Dev., Madras agric. J. 63: 537-541.

DeFluiter, H.J. (1941). Observations on white grubs and their control in Hevea plantations. Arch. Rubb. Cult. 25: 167-264.

Dejean, Comate DE M. LE. (1833). Catalogue des Coleopteres. DE LA Collection. Paris. P. 160.

Desai, M.T., and Patel, R.M. (1965). Some observations on the biology and control of white grubs in soil (Holotrichia nr. consanguinea) affecting groundnut in Gujarat. Indian J. Ent. 27: 89-94.

D'souza, G.I., Shamanna, H.V., and Venkitaramaiah, G.H. (1970). Control of cockchafers in coffee fields with systemic insecticides. Indian Coffee 34: 268-269.

Dwivedi, S.C., Ram, S., Prasad, N., and Dhari, K. (1976). Field evaluation of insecticides against white grub, Holotrichia consanguinea Blanch. Pesticides 10: 20-21.

Edgar, A.T. (1958). Pest and disease. In: Manual of Rubber Planting. The Incorporated Society of Planters, Kuala Lumpur. pp. 267-269.

Edwards, C.A. (1966). Insecticide residues in soils. Residue Rev. 13: 83-132.

Farrell, J.A.K. (1973). Effect of initial body weight and feeding on the fecundity and longevity of adults Costelytra zealandica. N. Z. J. agric. Sci. 16: 53-57.

Farrell, J.A.K., and Sweney, W.J. (1974). Plant resistence to the grass grub Costelytra zealandica. N. Z. J. agric. Res. 17: 69-72.

Finney, D.J. (1952). Probit analysis. 2nd Edn. Cambridge University Press. 318 p.

Fleming, W.E. (1972). Biology of the Japanese beetle. Tech. Bull. No. 1449, USDA, Washington, D.C. 129 p.

Gawaad, A.A.A., Ali, E.S.N.M., and Shazli, A.Y. (1971). Leaching of some soil insecticides in three Egyptian soils. Bull. Ent. Soc. Egypt (Economic). No.5: 23-26.

Gilbert, G.A., and Spragg, S.P. (1964). Iodimetric determination of Amylose. In: Methods in carbohydrate Chemistry Vol.4: Starch. (Ed. Whistler), Acad. Press. N.Y. pp. 168-169.

Gruner, L. (1974). Research on the behaviour during adult life of Phyllophaga plaei. Bl. Annales de Zoologie, Ecologie Animale 5: 385-424.

Gruner, L. (1975a)*. Investigations on the activity of various West Indian Scarabaeids with the aid of light traps and chemicals. Annals de Zoologie Ecologie Animale 7: 399-423. (Rev. appl. Ent. 64:1350).

Gruner, L. (1975b)*. Sequential sampling of population of white grubs of Phyllophaga patrueloides Paulian and forecasting damage in fields of sugarcane in Guadeloupe. Annales de Zoologie Ecologie Animale 7: 505-524. (Rev. appl. Ent. 64: 1350).

Gupta, B.D., and Avasthy, P.N. (1957). Observations on a new beetle pest of sugarcane crop in Bihar. Indian Sugar 7: 587-589, 591-594.

Guenzi, W.D., Beard, W.E., and Viets, F.G., Jr. (1971). Influence of soil treatment on persistence of six chlorinated hydrocarbon insecticides in the field. Soil Sci. Soc. Am. Proc. 35: 910-913.

Haq, A. (1962). Notes on the bionomics of Lachnosterna longipennis Bl. (Melolonthidae : Coleoptera). Indian J. Ent. 24: 220-221.

Harris, C.R., and Sans, W.W. (1969). Vertical distribution of residues of organochlorine insecticides in soils collected from six farms in South-Western Ontario. Proc. Ent. Soc. Ontario 100: 156-164.

Harris, C.R., and Sans, W.W. (1972). Behaviour of heptachlor epoxide in soil. J. econ. Ent. 65: 336-341.

Hauss, R. (1975)*. Methods and first results on the determination of the food plants of cockchafer grub Melolontha melolontha. Mitteilung aus der Biologischem Bundesanstalt fur Land-und Forstwirtschaft, Berlin. No. 163 pp. 72-77. (Rev. appl. Ent. 64: 524).

Hauss, R., and Schutte, F. (1976)*. On the polyphagous habits of the grubs of Melolontha melolontha L. on meadow and waste land plants. Angeiger fur Schadlings Kunde, Planzen Schutz umwett schutz 49: 129-132. (Rev. appl. Ent. 65: 1795).

Hurpin, B. (1956a)*. Influence des conditions atmospheriques sur les sorties pre-alimentaires du hanneton commun (Melolontha melolontha L.). Ann. Epiphyt. 7: 333-361. (Rev. appl. Ent. 43: 3).

Hurpin, B. (1956b)*. Influence do la temperature et de l'humidite die sur le developpement embryonnaire du hannton commun (Melolontha melolontha L.). Rev. Path. Veg. 35: 75-92 (Rev. appl. Ent. 45: 300-301).

Indira, P., and Sinha, S.K. (1969). Colorimetric method for determination of HCN in tubers and leaves of cassava (Manihot esculenta Cranz.). Indian J. agric. Sci. 39: 1021-1022.

Jepson, W.F. (1957). The biology of the sugarcane chafer beetle in Tanganyika. Bull. ent. Res. 47: 377-397.

Johnson, J., and Nair, M.R.G.K. (1966). A note on the control of the cocconut chafer grub Leucopholis coneophora Burm. Agric. Res. J. Kerala 4: 114.

Jose, V.T., and Kaul, C.L. (1978). Studies on control and movement of white grub, Holotrichia serrata (Febr.) in the heavy soils as influenced by soil moisture and temperature. Whitegrubs Newsl. 2: 17-18.

Joshi, R.K., Kaul, C.L., and Srivastava, B.P. (1969). Studies on chemical control of white grubs, Holotrichia consanguinea Bl. (Melolonthidae : Colooptera). Indian J. Ent. 31: 143-144.

Kalra, A.N., and Kulshreshtha, J.P. (1961). Studies on the biology and control of Lachnosterna consanguinea Blanch., a serious pest of sugarcane in Bihar (India). Bull. ent. Res. 52: 577-587.

Kadu, N.R., Tadas, P.L., Anvikar, D.G., Radke, S.G., Borle, M.N., and Mundiwale, S.K. (1976). Efficacy of insecticides against white grub, a serious polyphagous pest in Vidarbha. Indian J. Ent. 38: 381-383.

Kadu, N.R., Tadas, P.L., and Borle, M.N. (1978). Residual toxicity of BHC 10% and carbaryl 10% dusts in the soil to white grub affecting sorghum. Whitegrubs Newsl. 2: 37-38.

Kaul, C.L., Mathur, Y.K., and Srivastava, B.K. (1966). Laboratory evaluation of insecticides against the white grub Holotrichia consanguinea Blanch. Indian J. Ent. 28: 84-87.

Kavadia, V.S., and Gupta, H.C.L. (1976). Residues of insecticides in soils of Rajasthan - a brief resume. Univ. Udaipur Res. J. 14: 79-85 (Published in 1977).

Khanna, S.S., Gupta, K.M., and Ram, K.N. (1968). Sugarcane and its problem. Indian Sugar 18: 247-250.

Knutson, H., Kadmum, A.M., Hopkins, T.L., Swoyer, G.F., and Harvey, T.L. (1971). Insecticide usage and residues in a newly developed Great Plains Irrigation District. Pesticide monitoring 5: 17-27.

Koshy, P.K., and Sosamma, V.K. (1978). A handy tool for cocoonut research. Indian Cocon. J. 9: 4-5.

Krzymanska, J., and Mackiewicz, S. (1969)*. Aldrin and lindane residues in the soil when used in the form of superphosphate mixtures. Biuletyn Instytutu Ochrony Roslin. 45: 109-114. (Rev. appl. Ent. 61: 240-241).

Kumar, T.P. (1974). Chemical control of the arecanut white grub Leucopholis burmeisteri Br. Arecanut and Spices Bull. 6: 35.

Kumar, T.P., and Daniel, M. (1981). Studies on the control of soil grubs of arecanut palm. Pesticides 15(9): 29-30.

Kurian, C., Ponnamma, K.N., and Abdulla Koya, E.M. (1974). The concept philosophy and feasibility of integrated pest control with particular reference to coconut. Coconut. Bull. 5: 1-9.

Kushwah, B.L., Nelliat, E.V., Markose, V.T., and Sunny, A.F. (1973). Rooting pattern of coconut. Indian J. Agron. 18: 71-74.

Kushwaha, K.S., and Noor, A. (1976a). A review of progress in studies on soil insects infesting agricultural crops. Univ. Udaipur Res. J. 14: 1-61.

Kushwaha, K.S., and Noor, A. (1976b). Efficacy of some granular insecticides against grubs of Lachnosterna (=Holotrichia) serrata F. Univ. Udaipur Res. J. 14: 86-88.

Ladd, T.L. Jr., and Buriff, C.R. (1979). Japanese beetle: Influence of larval feeding on blue grass yield at two levels of soil moisture. J. econ. Ent. 72: 311-314.

Lal, S.S., and Pillai, K.S. (1977). Occurrence of white grub, Leucopholis coneophora B. (Melolonthinae : Coleoptera) as a pest of tubers of Dioscorea alata and D. esculenta in Kerala. J. Root Crops 3: 69.

Latreille, (1802). Hist. Nat. Crust. 3: 209.

Leefmans, S. (1915). De Cassava Oerete (The cassava grubs). Dept. Nijv. Landb. Handel-Med. van het Laboratorium voor Plantenziekten, Buitenzorg No.13: 118. (Rev. appl. Ent. 4: 82-83).

Lichtenstein, E.P. (1958). Movement of insecticides in soils under leaching and non-leaching conditions. J. econ. Ent. 51: 380-383.

Lichtenstein, E.P., and Schulz, K.R. (1959). Persistence of some chlorinated hydrocarbon insecticides as influenced by soil types, rate of application and temperature. J. econ. Ent. 52: 124-131.

Lichtenstein, E.P., Fishermann, T.W., and Schulz, K.R. (1971). Persistence and vertical distribution of DDT, lindane and aldrin residue 10 and 15 years after a single soil application. J. agric. Fd. Chem. 19: 718-721

Lopez, A.W. (1931a). Report of the Entomology Department. Ann. Rep. Res. Bur. Philipp. Sugar. Ass. 1929-30. pp. 145-172.

Lopez, A.W. (1931b). The use of antennae as a means of determining the sexes in Leucopholis irrorata adults. Philipp. J. Sci. 57: 759-761.

MacCready, R.H., Guggole, J., Silviera, V., and Owenz, H.S. (1950). Determination of starch and amylose in vegetables - application Peas. Anal. Chem. 29: 1156-1158.

MacLeay. (1819). Horae Entomologicae 1: 209.

Majumdar, N., and Teotia, T.P.S. (1965). Biology of Holotrichia serrata (Fabricius) a serious pest of Palas (Butea monosperma). Indian J. Ent. 27: 153-159.

Mammen, K.V. (1981). On the occurrence of white grub Schizonycha ruficollis (Melolonthinae : Coleoptera) as a pest of sugarcane in Kerala. Agric. Res. J. Kerala. 19: 131-132.

Martorell, F., and Goud, S.M. (1965). Status of important insect pests of sugarcane in Puerto Rico and their control. Proc. XII Cong. Int. Soc. Sug. Tech. Puerto Rico: 1268-1278.

Mathen, K., Kurian, C., and Mathew, J. (1964). Field studies on insecticidal control of coconut white grub Leucopholis coneophora B. Indian Cocon. J. 18: 101-108.

Mishchenko, A.A. (1974). A study of the soil fauna of pine stands in Kharkov district of Kharkov region. Vestnik Zoologii. 50: 20-24.

Nair, C.P.R., and Daniel, M. (1982). Root grubs Leucopholis burmeisteri Brenske. In: The Arecanut palm (Areca catechu Linn.) (Eds. Bavappa, K.V.A., et al.) Kasaragod. pp. 151-176.

Nath, V., and Srivastava, A.S. (1980). Relative toxicity of some insecticides to the final grubs of Holotrichia consanguinea Blanch. Indian J. Ent. 42: 667-670.

Nirula, K.K. (1958). Investigations on the pests of the coconut palm. Part V. Leucopholis coneophora Burm. Indian Cocon. J. 12: 10-39.

Nirula, K.K., and Menon, K.P.V. (1957). Insect pests of coconut palm in India. FAO Plant Prot. Bull 6(1): 1-5.

Nirula, K.K., Antony, J., and Menon, K.P.V. (1952). A new pest of coconut palm in India. Indian Cocon. J. 5: 137-140.

Otanes, F.Q. (1925). Some observations on root grubs (Leucopholis irrorata Chevr.) in the Philippines and suggestions for their control. Philipp. agric. Rev. 17(2): 109-119.

Otanes, F.Q. (1927). "The toy beetle" Leucopholis irrorata Chevr. in the Philippines, a serious pest. Philipp. agric. Rev. 18: 555-557

Otanes, F.Q., and Karganilla, L.T. (1940). Insect and other pests of corn. Philipp. J. Agric. 11: 403.

Otanes, F.Q., and Karganilla, L.T. (1947). Insect and other pests of corn. Philipp. J. Agric. 13: 207-235.

Pal, S.K., Kushwaha, K.S. (1977)*. Symposium on Insects and Environment, Delhi. (Abstr.) P. 43: (Univ. Udaipur Res. J. 14: 79-85).

Parasnath and Janardan Singh (1981). Monitoring of root grubs in Varanasi and Mirzapur districts of eastern Uttar Pradesh. Pesticides 15: 7-9.

Patel, R.M., Patel, G.G., and Vyas, H.N. (1967). Further observation on the biology and control of white grubs Holotrichia sp. in soil affecting groundnut in Gujarat. Indian J. Ent. 29: 170-176.

Patil, S.P. (1978). Studies on larval taxonomy of white grubs in Karnataka. Ph.D. Thesis, UAS, Bangalore. 144 p.

Patil, B.R., and Hasabe, B.M. (1981). Studies on the bionomics of white grub Holotrichia serrata F. In: Progress on white grubs Research in India. (Ed. Veeresh, G.K.) UAS, Hebbal. pp. 115-120.

Patil, B.R., Hasabe, B.M., and Ajri, D.S. (1981). Chemical control of white grub Holotrichia serrata Fabr. infesting groundnut, paddy and sorghum. Indian J. Ent. 43: 232-236.

Prasad, S.K. (1977). Chemical control of white grub Lachnosterna consanguinea on groundnut. Indian J. Ent. 37: 324-325.

Prasad, S.K., and Thakur, C. (1959). White grub Lachnosterna consanguinea Blanch., a new menace to sugarcane. Indian J. Ent. 21: 184-189.

Puttarudraiah, M., and Channa Basavanna, G.P. (1957). Some new insects and mites on areca palm in Mysore-III. Arecanut J. 8: 10-11.

Rai, B.K., Joshi, H.C., Rathore, Y.K., Dutta, S.H., and Shinde, V.K.R. (1969). Studies on the bionomics and control of white grub Holotrichia consanguinea Blanch. in Lalsot district, Jaipur. Indian J. Ent. 31: 132-142.

Mishchenko, A.A. (1974). A study of the soil fauna of pine stands in Kharkov district of Kharkov region. Vestnik Zoologii. 50: 20-24.

Nair, C.P.R., and Daniel, M. (1982). Root grubs Leucopholis burmeisteri Brenske. In: The Arecanut palm (Areca catechu Linn.) (Eds. Bavappa, K.V.A., et al.) Kasaragod. pp. 151-176.

Nath, V., and Srivastava, A.S. (1980). Relative toxicity of some insecticides to the final grubs of Holotrichia consanguinea Blanch. Indian J. Ent. 42: 667-670.

Nirula, K.K. (1958). Investigations on the pests of the coconut palm. Part V. Leucopholis coneophora Burm. Indian Cocon. J. 12: 10-39.

Nirula, K.K., and Menon, K.P.V. (1957). Insect pests of cocconut palm in India. FAO Plant Prot. Bull 6(1): 1-5.

Nirula, K.K., Antony, J., and Menon, K.P.V. (1952). A new pest of coconut palm in India. Indian Cocon. J. 5: 137-140.

Otanes, F.Q. (1925). Some observations on root grubs (Leucopholis irrorata Chevr.) in the Philippines and suggestions for their control. Philipp. agric. Rev. 17(2): 109-119.

Otanes, F.Q. (1927). "The toy beetle" Leucopholis irrorata Chevr. in the Philippines, a serious pest. Philipp. agric. Rev. 18: 555-557.

Otanes, F.Q., and Karganilla, L.T. (1940). Insect and other pests of corn. Philipp. J. Agric. 11: 403.

Otanes, F.Q., and Karganilla, L.T. (1947). Insect and other pests of corn. Philipp. J. Agric. 13: 207-235.

Pal, S.K., Kushwaha, K.S. (1977)*. Symposium on Insects and Environment, Delhi. (Abstr.) P. 43. (Univ. Udaipur Res. J. 14: 79-85).

Parasnath and Janardan Singh (1981). Monitoring of root grubs in Varanasi and Mirzapur districts of eastern Uttar Pradesh. Pesticides 15: 7-9.

Patel, R.M., Patel, G.G., and Vyas, H.N. (1967). Further observation on the biology and control of white grubs Holotrichia sp. in soil affecting groundnut in Gujarat. Indian J. Ent. 29: 170-176.

Patil, S.P. (1978). Studies on larval taxonomy of white grubs in Karnataka. Ph.D. Thesis, UAS, Bangalore. 144 p.

Patil, B.R., and Hasabe, B.M. (1981). Studies on the bionomics of white grub Holotrichia serrata F. In: Progress on white grubs Research in India. (Ed. Veeresh, G.K.) UAS, Hebbal. pp. 115-120.

Patil, B.R., Hasabe, B.M., and Ajri, D.S. (1981). Chemical control of white grub Holotrichia serrata Fabr. infesting groundnut, paddy and sorghum. Indian J. Ent. 43: 232-236.

Prasad, S.K. (1977). Chemical control of white grub Lachnosterna consanguinea on groundnut. Indian J. Ent. 37: 324-325.

Prasad, S.K., and Thakur, C. (1959). White grub Lachnosterna consanguinea Blanch., a new menace to sugarcane. Indian J. Ent. 21: 184-189.

Puttarudraiah, M., and Channa Basavanna, G.P. (1957). Some new insects and mites on areca palm in Mysore-III. Arecanut J. 8: 10-11.

Rai, B.K., Joshi, H.C., Rathore, Y.K., Dutta, S.K., and Shinde, V.K.R. (1969). Studies on the bionomics and control of white grub Holotrichia consanguinea Blanch. in Lalsot district, Jaipur. Indian J. Ent. 31: 132-142.

Rajamani, S., and Nambiar, K.K.N. (1970). Pests of Arecanut palm. Indian Farm. 20: 23.

Rao, K.S.N. (1963). The white grub pest of the arecanut palm. Arecanut J. 14: 161-162.

Rao, K.S.N., and Bavappa, K.V.A. (1961). Nursery diseases and pests of arecanut and their control. Arecanut J. 12: 136-139.

Rao, K.S.N., Naidu, G.V.B., and Bavappa, K.V.A. (1961). The white grub pest of arecanut. Arecanut J. 12: 22-25.

Rao, Sripath. B. (1965). Pests of Hevea plantation in Malaya. Rubbe Res. Inst., Kuala Lumpur. 898 p.

Rao, Sripath. B. (1966). Cockchafer attack in Malayan rubber plantations and integrated control. Proc. XI Pacif. Sci. Congr., Tokyo. pp. 54-62.

Raodeo, A.K., and Deshpande, S.V. (1981). Strategy and organisation of white grub control campaign at Village Ratoli Dist. Manded, Maharashtra State. In: Progress on white grubs research in India. (Ed. Veeresh, G.K.) UAS, Hebbal, pp. 104-114.

Ritcher, O.P. (1958). Biology of scarabaeidae. In: Ann. Rev. Ent. (Eds. Steinhaus, E.A., and Smith, R.F.), California, USA. 3: 311-334.

Sachan, J.N., and Pal, S.K. (1974). White grubs and their control at the Central Arid Zone Research Institute, Jodhpur. Whitegrubs Newsl. 1(1): 20-24.

Sachan, J.N., and Pal, S.K. (1976). Insecticides and cakes for the control of white grub Holotrichia insularis in Western Rajasthan. Pesticides 10(6): 37-38.

Schechter, M.S., and Hornstein, I. (1952). Colorimetric determination of benzene hexachloride, Anal. Chem. 24: 544.

Schwardt, H.H., and Whitcomb, W.H. (1943). Life history of the European chafer, Amphimallon majalis (Razoum). J. econ. Ent. 36: 345.

Sekhar, P.S. (1958). Studies on the cockchafer, Leucopholis coneophora Burm. a pest of coconut palm and other intercultivated crops. Indian Cocon. J. 11(2): 67-80.

Seshadri, A.R. (1957). Unseen denizens of the earth. Cocon. Bull. 9: 194-199.

Sharma, S.K., and Shinde, V.K.R. (1970a). Toxicity of some pesticides to grub of Lachnosterna consanguinea. J. econ. Ent. 63: 1662-1663.

Sharma, S.K., and Shinde, V.K.R. (1970b). Control of white grub Lachnosterna consanguinea Blanch. PANS 16: 176-179.

Sharma, S.K., and Shinde, V.K.R. (1973). White grub menace in winter crops and its control. Madras agricec J. 60: 587.

Sheshadri, S.N. (1969). Study on the biology and control of white grub, Leucopholis burmeisteri. Ann. Rep. Central Plant. Crops Res. Inst., Kasaragod P. 177.

Shinde, V.K.R., Sharma, S.K., and Puri, M.K. (1980). Relative potency of insecticides against Lachnosterna (=Holotrichia) consanguinea Blanch. in different types of soils. Entomon 5: 105-107.

Shorey, H.H., and Gyrisco, G.G. (1960). Effect of soil temperature and moisture on the vertical distribution of European chafer larvae. Ann. ent. Soc. Am. 53: 666-670.

Sithananthem, S. (1978). White grubs on sugarcane in India. Whitegrubs Newsl. 2: 2-3.

Srivastava, B.K., and Khan, R.M. (1963). Bionomics and control of Holotrichia insularis (Melolonthidae : Coleoptera). Indian J. Ent. 26: 347-354.

Srivastava, A.S., and Mathur, Y.K. (1979). Recent advances - Bionomics and control of white grubs. A guide for the control of white grub. 2nd Edn. Dept. of Entomology, C.S.Azad University of Agri. and Tech., Kanpur. 14 p.

Srivastava, B.P., and Yadava, P.R. (1977). Dissipation of BHC in clay loam soil under the cover of maize (Zea mays) crop. Indian J. Pl. Prot. 5: 62-69.

Srivastava, A.S., Nigam, P.K., and Srivastava, K.M. (1971). Field trials against Holotrichia consanguinea Blanch. with certain soil insecticides. Int. Pest Control 13: 22-23.

Srivastava, A.S., Mathur, Y.K., Upadhyay, K.D., Srivastava, J.P., and Ram Anjor (1982). Seed treatment of groundnut with certain insecticides for the control of white grub (Holotrichia consanguinea). Pestology 6: 15-17.

Stewart, D.K.R., and Fox, C.J.S. (1971). Persistence of organochlorine insecticides and their metabolites in Nova Scotian soil. J. econ. Ent. 64: 367-371.

Sukhija, R.S. (1978). Holotrichia consanguinea Bl. a new pest of sunflower in Punjab. Whitegrubs Newsl. 2: 26-27.

Tashiro, H., Gyrisco, G.G., Gambrell, F.L., Fiori, B.J., and Breitfeld, H. (1969). Biology of the European chafer Amphimallon majalis (Coleoptera : Scarabaeidae) in North-eastern United States. Cornell Univ. Geneva, N.Y. Bull. No. 828: 71 p.

Teetes, G.L. (1973). Phyllophaga crinita damage, assessment and control in grain sorghum and wheat. J. econ. Ent. 66: 773-776.

Uichanco, L.B. (1928). A conspectus of injurious and beneficial insects of sugarcane in the Philippines, with special reference to Luzon and Negros. Rep. Comm. Cane varieties, Diseases and Fertilizers. Sixth Ann. Conv. Philipp. Sugar. Ass. 16 p.

Uichanco, L.B. (1930). Biological notes on adult Leucopholis irrorata Chevr., with a consideration of beetle collecting campaigns as a method of control against white grub. Philipp. Agric. 19: 133-155.

Valenta, V., and Gavells, V. (1970). The complex of measures for the control of cockchafers (Melolontha melolontha L., M. hippocastani F.) Acta Entomologica Lituanica 1: 155-162.

Valsala, P.G. (1958). A white grub attacking roots of coconut palm. Cocon. Bull. 12: 240-243.

Veeresh, G.K. (1973a). Studies on the melolonthid beetles (Coleoptera : Scarabacidae) of Mysore State with special reference to the Biology and control of Holotrichia serrata F. Ph.D. Thesis submitted to the University of Agricultural Sciences, Hebbal. 144 p.

Veeresh, G.K. (1973b). Preliminary evaluation of insecticides for the control of root grubs Holotrichia serrata. Pesticides 7: 27.

Veeresh, G.K. (1976). Coconut root grubs and their control in Karnataka. Int. Symp. Cocon. Res. & Dev. Kasaragod, Dec. 28-31, 1976. (Abstr.) P. 40.

Veeresh, G.K. (1977). Studies on the root grubs in Karnataka. UAS Monograph series No.2, UAS, Hebbal; 87 p.

Veeresh, G.K. (1981). Larval taxonomy of white grubs with special reference to Melolonthine beetle. Final Report ICAR Ad-hoc Project on Larval Taxonomy, 1977-1980. 93 p.

Veeresh, G.K., and Viswanath, B.N. (1983). Crop losses due to white grubs. All India Semin. on Crop losses due to insect pests. Hyderabad. (Abstr.) Section 18: 5-6.

Veeresh, G.K., Veeraraju, P.V., Gubbaiah, and Vijayamohana Reddy, N. (1976). Efficacy of certain soil insecticides against root grubs (Holotrichia serrata F.) under irrigated and unirrigated conditions in tropical soils. Soil Biol. & Ecol. in India, UAS Tech. Ser. No.22: 326-334.

Veeresh, G.K., Vijayendra, M., Vijayamohana Reddy, N., Rajanna, C., and Rai, P.S. (1982). Bioecology and management of areca white grubs (Leucopholis spp.) (Melolonthinae : Scarabaeidae). Symp. Silver Jubilee of Arecanut Research, Vittal, Dec. 1982 (Proc. in press).

Venkitaramaiah, G.H. (1969). Biology and control of cockchafer grub in coffee plantation. Pesticides 2: 14-18.

Venkitaramaiah, G.H., and Shamanna, H.V. (1973). Further observations on cockchafer control. Indian Coffee 37: 289-296.

Venkitaramaiah, G.H., and Singh, M.B.D. (1972). Pesticide residue in coffee plantations. J. Plant Crops 1: 153-157.

Vishwanath (1980). Relative effectiveness of some chemical insecticides against white grub Holotrichia consanguinea. Indian J. Pl. Prot. 8: 45-48.

Vora, V.J., Bharodia, R.K., and Kapadia, M.N. (1978). Chemical control of white grub. Whitegrubs Newsl. 2: 38-39.

Wiese, I.H., and Basson, N.C.J. (1966). The degradation of some persistent chlorinated hydrocarbon insecticides applied to different soil types. S. Afr. J. agric. Sci. 9: 945-969.

Wightman, J.A. (1973). Effect of environment on Costelytra zealandica. 2: Effect of temperature and soil moisture on duration and survival of the egg stage. N. Z. J. Sci. 16: 41-52.

Wightman, J.A., and Fowler, M. (1974). Rearing Costelytra zealandica. 5: Decontamination of egg. N. Z. J. Zool. 1: 225-230.

Wilkinson, A.T., and Finlayson, D.G. (1964). Toxic residues in soil 9 years after treatment with aldrin and heptachlor. Science (N. Y.) 143: 681-682.

Wilson, E.R.L. (1978). White clover and grass grub. II Screening 74 overseas lines for resistance and tolerance. N. Z. J. agric. Res. 21: 723-726.

Yadava, C.P.S. (1981). Studies on white grub Holotrichia consanguinea Blanch. In: Progress on white grubs Research in India. (Ed. Veeresh, G.K.) UAS, Hebbal. pp. 80-103.

Yadava, C.P.S., and Yadava, S.R.S. (1973). Field trials with certain commonly used insecticides against white grub Holotrichia consanguinea Blanch. infesting groundnut. Indian J. Ent. 35: 329-332.

Yadava, C.P.S., Saxena, R.C., Mishra, R.H., and Dadheech, L.M. (1977). Evaluation of some granular insecticides for control of grubs of Holotrichia consanguinea. Indian J. agric. Sci. 47: 139-142.

Zivanovic, V. (1976). Status of the population of the common cockchafer Melolontha melolontha in western Serbia during the flight year 1974. Acta Entomologica Jugoslavic 11: 93-100.

*Original not seen.

APPENDICES

Appendix 1. Distribution of adults of *L. consophora* in different depths of soil in different periods of the year.

location	year	depth (cm)	Apr. a	Apr. b	May a	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Total
Thaghakkara	1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	1	3	1	0	0	0	5
		30-45	0	0	0	0	1	0	1	1	0	0	0	0	3
		45-60	0	0	0	1	1	3	1	0	0	0	0	0	6
		60-100	0	0	0	4	3	1	0	2	0	0	0	0	10
		Total	0	0	0	5	5	4	3	6	1	0	0	0	24
	1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	2	1	1	0	0	0	4
		30-45	0	0	0	0	1	3	2	1	2	1	1	1	12
		45-60	0	0	0	0	1	2	2	1	0	1	0	0	7
		60-100	0	0	0	0	0	4	4	0	1	0	0	0	9
		Total	0	0	0	0	2	9	10	3	4	2	1	1	32
	1980	0-15	0	0	0	0	0	0	0	2	1	2	0	0	5
		15-30	0	0	0	0	0	0	0	2	4	2	0	0	8
		30-45	0	0	0	1	5	3	3	7	3	0	0	0	22
		45-60	0	0	0	1	2	2	2	3	1	1	0	0	12
		60-100	0	0	0	0	3	7	1	7	5	4	0	0	27
		Total	0	0	0	2	10	12	6	21	14	9	0	0	74
Vazhuvadi	1978	0-15	0	0	0	0	0	1	1	0	0	0	0	0	2
		15-30	0	0	0	0	0	0	0	0	0	0	0	0	0
		30-45	0	0	0	3	7	0	1	1	0	0	0	0	12
		45-60	0	0	0	0	0	2	3	2	1	0	0	0	8
		60-100	0	0	0	7	7	6	1	2	1	0	0	0	24
		Total	0	0	0	10	14	9	6	5	2	0	0	0	46
	1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	4	4	5	2	2	1	0	18
		30-45	0	0	0	0	5	3	7	2	2	2	1	0	22
		45-60	0	0	0	0	5	7	2	2	1	1	0	0	18
		60-100	0	0	0	1	1	0	1	3	0	2	0	0	8
		Total	0	0	0	1	11	14	14	12	5	7	2	0	66
	1980	0-15	0	0	1	0	0	0	0	0	0	0	0	0	1
		15-30	2	2	1	0	0	1	0	1	0	1	0	0	8
		30-45	0	0	3	1	2	1	1	2	0	0	0	0	10
		45-60	0	0	0	3	3	3	2	1	1	0	0	0	13
		60-100	0	0	0	2	5	3	2	3	1	1	0	0	17
		Total	2	2	5	6	10	8	5	7	2	2	0	0	49

Population given is the total number of adults in 10 pits.

Appendix 2. Distribution of eggs of *L. conophora* in different depths of soil in different periods of the year.

location	year	depth (cm)	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	total
Thachakkawa	1978	0-15	0	0	5	10	0	0	0	0	0	15
		15-30	0	4	10	32	11	0	0	0	0	57
		30-45	0	12	0	11	0	18	0	0	0	41
		45-60	0	0	0	0	0	0	0	0	0	0
		60-100	16	19	0	0	25	0	0	0	0	60
		Total	16	35	15	53	36	18	0	0	0	173
	1979	0-15	0	0	0	0	0	0	0	0	0	0
		15-30	0	3	10	0	18	21	10	0	0	62
		30-45	0	19	17	32	17	0	1	0	0	86
		45-60	0	0	22	27	0	23	12	0	0	84
		60-100	0	17	0	0	4	0	0	0	0	21
		Total	0	39	49	59	39	44	23	0	0	253
	1980	0-15	1	0	5	0	0	0	2	0	0	8
		15-30	0	3	13	0	30	0	11	0	0	59
		30-45	0	18	14	40	20	33	28	0	0	153
		45-60	0	0	0	30	0	31	33	0	0	94
		60-100	10	21	0	10	17	0	0	0	0	58
		Total	11	44	32	80	67	64	74	0	0	372
Vazhavadi	1978	0-15	0	1	0	0	0	0	0	0	0	1
		15-30	0	0	0	0	0	0	0	0	0	0
		30-45	0	9	0	11	2	15	0	0	0	37
		45-60	4	0	0	16	13	0	0	0	0	33
		60-100	86	82	0	0	5	0	0	0	0	173
		Total	90	92	0	27	20	15	0	0	0	244
	1979	0-15	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	2	1	25	0	23	11	25	87
		30-45	0	11	3	14	30	51	30	24	30	193
		45-60	0	0	32	3	0	0	0	5	0	40
		60-100	0	58	41	7	0	0	0	0	0	106
		Total	0	69	78	25	55	51	53	40	55	426
	1980	0-15	1	2	0	0	1	0	0	0	0	4
		15-30	22	0	0	0	0	0	27	0	0	49
		30-45	13	9	18	7	17	30	33	0	0	127
		45-60	0	0	11	30	21	20	0	0	0	82
		60-100	0	51	40	19	0	0	0	0	0	110
		Total	36	62	69	56	39	50	60	0	0	372

Population given is the total number of eggs in 10 pits.
a = first fortnight of the month; b = second fortnight of the month

Appendix 3. Distribution of first instar grubs of *L. consophera* in different depths of soil in different periods of the year.

location	year	depth (cm)	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	total
Thazhakkara	1978	0-15	2	0	0	22	7	7	9	9	7	2	45
		15-30	1	3	5	3	16	17	28	25	17	4	119
		30-45	0	1	8	5	1	1	17	5	11	1	50
		45-60	0	0	1	0	1	0	1	6	3	0	12
		60-100	0	0	1	0	0	6	0	2	0	0	9
		Total	3	4	15	10	25	31	55	47	38	7	235
	1979	0-15	0	4	0	11	13	11	12	9	0	0	60
		15-30	0	1	10	18	10	11	17	25	3	2	97
		30-45	0	0	17	7	1	2	4	6	7	0	44
		45-60	0	0	22	2	1	0	3	7	0	0	35
		60-100	0	0	0	1	2	0	0	1	0	0	4
		Total	0	5	49	39	27	24	36	48	10	2	240
Vazhuvadi	1978	0-15	3	1	1	7	5	6	14	2	3	0	42
		15-30	3	3	3	9	13	10	14	2	2	3	62
		30-45	0	2	3	9	8	5	10	4	7	0	48
		45-60	6	0	1	4	1	0	2	1	1	2	18
		60-100	1	0	0	1	0	0	0	3	0	0	5
		Total	13	6	8	30	27	21	40	12	13	5	175
	1979	0-15	0	2	2	3	4	4	7	10	3	1	36
		15-30	0	2	4	11	8	10	3	8	2	4	52
		30-45	0	1	6	4	12	9	3	1	4	1	41
		45-60	0	0	1	7	5	0	3	0	4	1	21
		60-100	0	0	0	0	0	0	2	0	2	0	4
		Total	0	5	13	25	29	23	18	19	15	7	154

Population given is the total number of grubs in 10 pits.
a = first fortnight of the month; b = second fortnight of the month.

Appendix 4. Distribution of second instar grubs of L. coneophora in different depths of soil in different periods of the year.

location	year	depth (cm)	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	total
Thazhakkara	1978	0-15	0	1	1	0	2	3	2	3	0	0	0	0	12
		15-30	0	6	5	2	1	8	4	7	5	0	0	0	38
		30-45	0	1	1	3	18	3	1	7	3	0	0	0	37
		45-60	0	0	0	1	8	3	0	1	0	0	0	0	13
		60-100	0	0	0	6	0	0	0	0	0	0	0	0	6
		Total	0	8	7	12	29	17	7	18	8	0	0	0	106
	1979	0-15	2	1	3	6	12	2	0	2	3	0	0	0	31
		15-30	1	7	4	4	1	14	7	10	3	0	0	0	51
		30-45	0	1	1	2	17	3	2	3	0	0	0	0	29
		45-60	0	0	1	1	8	3	1	1	0	0	0	0	15
		60-100	0	0	0	0	0	0	0	1	0	0	0	0	1
		Total	3	9	9	13	38	22	10	17	6	0	0	0	127
Vazhuvadi	1978	0-15	0	0	5	0	1	14	0	0	0	0	0	0	10
		15-30	1	2	6	4	1	4	1	2	4	0	0	0	25
		30-45	1	7	0	1	10	3	5	5	2	0	0	0	34
		45-60	0	1	0	3	0	1	1	1	2	0	0	0	9
		60-100	0	1	0	1	3	0	0	0	2	0	0	0	7
		Total	2	11	11	9	15	12	7	8	10	0	0	0	85
	1979	0-15	0	0	2	4	0	3	1	1	0	0	0	0	11
		15-30	0	0	0	1	2	2	2	4	7	0	0	0	18
		30-45	0	0	3	3	0	4	1	6	0	0	0	0	17
		45-60	0	0	0	0	0	4	1	3	0	0	0	0	8
		60-100	0	0	0	0	0	2	0	1	0	0	0	0	3
		Total	0	0	5	8	2	15	5	15	7	0	0	0	57

Population given is the total number of grubs in 10 pits.
a = first fortnight of the month; b = second fortnight of the month.

Appendix 5. Distribution of third instar grubs of L. concephora in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	0	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

ifferent depths of soil in different periods of the year.

Feb.		Marc		Apr.		May		Jun.		Jul.		total
a	b	a	b	a	b	a	b	a	b	a	b	
0	1	1	7	3	6	2	4	0	0	0	0	60
0	9	4	21	20	15	7	7	0	0	2	0	181
3	6	6	16	11	10	3	4	2	1	4	0	132
8	7	6	6	3	2	0	3	4	1	4	0	88
4	13	0	1	0	1	0	4	6	0	1	0	44
15	36	17	31	37	34	12	24	12	2	11	0	303
0	2	0	0	0	1	3	0	0	0	0	0	25
1	3	4	4	1	4	11	1	0	1	0	0	72
2	1	8	3	0	1	0	0	3	0	0	0	65
2	3	3	4	0	2	2	1	2	0	0	0	48
9	3	2	8	1	3	1	0	2	0	0	0	46
14	16	19	19	2	11	19	2	7	1	0	0	255
2	2	0	0	0	0	0	0	0	0	0	0	18
1	2	1	1	0	0	3	0	0	0	0	0	47
4	3	1	1	1	3	1	2	1	1	0	0	64
8	3	4	8	11	7	4	1	0	1	00	0	76
2	3	8	2	8	10	0	2	1	1	0	0	53
17	17	14	12	20	20	8	3	2	3	0	0	258
0	1	3	2	0	1	1	0	0	0	0	0	22
3	4	4	7	4	2	8	0	4	0	0	0	93
8	3	7	9	9	3	1	1	3	2	0	0	79
3	1	1	3	0	1	0	1	1	2	0	0	33
1	2	1	7	0	0	0	9	0	0	0	0	41
15	13	16	28	13	9	9	11	10	4	0	0	288
0	2	0	1	1	9	0	1	0	0	0	0	19
2	7	2	2	4	28	3	1	4	2	12	7	103
0	4	3	7	3	3	1	1	7	1	0	0	72
4	4	9	13	1	1	1	2	0	0	0	0	54
2	3	8	3	1	0	0	0	0	0	0	0	44
8	22	24	28	10	41	3	3	11	3	12	7	292
0	0	0	0	0	0	1	0	0	0	0	0	10
0	0	1	0	2	2	1	0	4	0	0	0	30
3	3	8	7	2	4	0	0	3	2	0	0	67
8	3	3	9	4	4	0	1	2	1	0	0	67
3	4	3	3	2	0	0	7	1	2	0	0	36
14	10	19	19	10	10	2	8	12	3	0	0	210

Appendix 6. Distribution of pupae of *L. concophora* in different depths of soil in different periods of the year.

location	year	depth (cm)	Mar. a	Mar. b	Apr. a	Apr. b	May a	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	total
Thazhakkara	1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	0	0	0	0	0	0
		30-45	0	0	0	0	2	0	0	1	0	1	0	0	4
		45-60	0	0	0	0	0	2	0	0	1	0	0	0	3
		60-100	0	0	0	0	5	11	5	0	3	0	0	0	24
		Total	0	0	0	0	7	13	5	1	4	1	0	0	31
	1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	3	0	3	0	0	6
		30-45	0	0	0	1	1	0	0	2	4	0	1	1	10
		45-60	0	0	2	1	0	2	3	1	7	0	1	1	18
		60-100	0	0	0	0	3	1	2	7	5	0	1	0	14
		Total	0	0	2	2	4	3	5	13	11	3	3	2	48
	1980	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	0	0	0	0	0	0
		30-45	0	0	1	1	2	4	2	4	0	1	0	0	15
		45-60	0	0	1	2	2	1	1	3	2	3	0	0	15
		60-100	0	0	2	2	2	0	6	9	7	4	0	0	32
		Total	0	0	4	5	6	5	9	16	9	8	0	0	62
Vazhuvadi	1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	1	2	0	0	0	0	0	0	3
		30-45	0	0	0	0	0	3	2	2	1	0	0	0	8
		45-60	0	0	0	0	1	0	7	3	2	0	0	0	13
		60-100	0	0	0	0	3	18	16	5	0	0	2	0	44
		Total	0	0	0	0	5	23	25	10	3	0	2	0	68
	1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	3	3	3	0	0	9
		30-45	0	0	0	0	1	0	8	5	2	3	0	0	19
		45-60	1	2	0	4	1	2	5	1	0	2	0	0	18
		60-100	0	0	0	0	1	1	9	0	1	0	0	0	12
		Total	1	2	0	4	3	3	22	9	6	8	0	0	58
	1980	0-15	0	0	2	1	0	0	0	0	0	0	0	0	3
		15-30	0	0	2	0	2	0	6	0	0	0	0	0	4
		30-45	2	2	4	3	4	1	2	1	2	1	0	0	22
		45-60	1	2	4	7	1	3	7	4	1	0	0	0	30
		60-100	1	0	10	0	0	0	9	7	1	1	0	0	29
		Total	4	4	22	11	7	4	18	12	4	2	0	0	88

Population given is the total number of pupae in 10 pits.
a = first fortnight of the month; b = second fortnight of the month.

Appendix 4. Distribution of second instar grubs of L. oeneophora in different depths of soil in different periods of the year.

location	year	depth (cm)	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	total
Thazhakkara	1978	0-15	0	1	1	0	2	3	2	3	0	0	0	0	12
		15-30	0	6	5	2	1	8	4	7	5	0	0	0	38
		30-45	0	1	1	3	18	3	1	7	3	0	0	0	37
		45-60	0	0	0	1	8	3	0	1	0	0	0	0	13
		60-100	0	0	0	6	0	0	0	0	0	0	0	0	6
		Total	0	8	7	12	29	7	7	18	8	0	0	0	106
	1979	0-15	2	1	3	6	12	2	0	2	3	0	0	0	31
		15-30	1	7	4	4	1	14	7	10	3	0	0	0	51
		30-45	0	1	1	2	17	3	2	3	0	0	0	0	29
		45-60	0	0	1	1	8	3	1	1	0	0	0	0	15
		60-100	0	0	0	0	0	0	0	1	0	0	0	0	1
		Total	3	9	9	13	38	22	10	17	6	0	0	0	127
Vazhuvadi	1978	0-15	0	0	5	0	1	14	0	0	0	0	0	0	10
		15-30	1	2	6	4	1	4	1	2	4	0	0	0	25
		30-45	1	7	0	1	10	3	5	5	2	0	0	0	34
		45-60	0	1	0	3	0	1	1	1	2	0	0	0	9
		60-100	0	1	0	1	3	0	0	0	2	0	0	0	7
		Total	2	11	11	9	15	12	7	8	10	0	0	0	85
	1979	0-15	0	0	2	4	0	3	1	1	0	0	0	0	11
		15-30	0	0	0	1	2	2	2	4	7	0	0	0	18
		30-45	0	0	3	3	0	4	1	6	0	0	0	0	17
		45-60	0	0	0	0	0	4	1	3	0	0	0	0	8
		60-100	0	0	0	0	0	2	0	1	0	0	0	0	3
		Total	0	0	5	8	2	15	5	15	7	0	0	0	57

Population given is the total number of grubs in 10 pits.
a = first fortnight of the month; b = second fortnight of the month.

Appendix 5. Distribution of third instar grubs of L. conesphora in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	0	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	3	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

Appendix 4. Distribution of second instar grubs of L. coneophora in different depths of soil in different periods of the year.

location	year	depth (cm)	Jul. a	Jul. b	Aug. a	Aug. b	Sep. a	Sep. b	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	total
Thazhakkara	1978	0-15	0	1	1	0	2	3	2	3	0	0	0	0	12
		15-30	0	6	5	2	1	8	4	7	5	0	0	0	38
		30-45	0	1	1	3	18	3	1	7	3	0	0	0	37
		45-60	0	0	0	1	8	3	0	1	0	0	0	0	13
		60-100	0	0	0	6	0	0	0	0	0	0	0	0	6
		Total	0	8	7	12	29	17	7	18	8	0	0	0	106
	1979	0-15	2	1	3	6	12	2	0	2	3	0	0	0	31
		15-30	1	7	4	4	1	14	7	10	3	0	0	0	51
		30-45	0	1	1	2	17	3	2	3	0	0	0	0	29
		45-60	0	0	1	1	8	3	1	1	0	0	0	0	15
		60-100	0	0	0	0	0	0	0	1	0	0	0	0	1
		Total	3	9	9	13	38	22	10	17	6	0	0	0	127
Vazhuvadi	1978	0-15	0	0	5	0	1	14	0	0	0	0	0	0	10
		15-30	1	2	6	4	1	4	1	2	4	0	0	0	25
		30-45	1	7	0	1	10	3	5	5	2	0	0	0	34
		45-60	0	1	0	3	0	1	1	1	2	0	0	0	9
		60-100	0	1	0	1	3	0	0	0	2	0	0	0	7
		Total	2	11	11	9	15	12	7	8	10	0	0	0	85
	1979	0-15	0	0	2	4	0	3	1	1	0	0	0	0	11
		15-30	0	0	0	1	2	2	2	4	7	0	0	0	18
		30-45	0	0	3	3	0	4	1	6	0	0	0	0	17
		45-60	0	0	0	0	0	4	1	3	0	0	0	0	8
		60-100	0	0	0	0	0	2	0	1	0	0	0	0	3
		Total	0	0	5	8	2	15	5	15	7	0	0	0	57

Population given is the total number of grubs in 10 pits.
a = first fortnight of the month; b = second fortnight of the month.

Appendix 5. Distribution of third instar grubs of L. coneophora in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	0	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

Appendix 5. Distribution of third instar grubs of L. consephora in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	0	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

Appendix 5. Distribution of third instar grubs of L. concephora in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	∞	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	5
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	15	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	3	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

Appendix 5. Distribution of third instar grubs of *L. coneophora* in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	Φ	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

Appendix 5. Distribution of third instar grubs of *L. coneophora* in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	0	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

Appendix 5. Distribution of third instar grubs of *L. coneophora* in

location	year	depth (cm)	Oct. a	Oct. b	Nov. a	Nov. b	Dec. a	Dec. b	Jan. a	Jan. b
Thazhakkara	1977-78	0-15	1	12	0	12	6	6	0	0
		15-30	0	29	7	22	22	12	1	3
		30-45	0	10	5	18	16	7	6	4
		45-60	0	6	6	9	8	3	8	2
		60-100	0	3	2	0	2	0	2	4
		Total	1	60	20	61	54	28	17	13
	1978-79	0-15	0	0	0	5	4	4	2	2
		15-30	0	0	5	13	7	6	4	5
		30-45	0	2	9	10	7	8	8	3
		45-60	2	2	5	3	7	2	4	2
		60-100	1	0	3	3	3	0	2	3
		Total	3	4	22	34	28	20	20	15
	1979-80	0-15	0	0	0	6	3	2	1	2
		15-30	1	1	5	13	7	4	3	5
		30-45	1	1	11	9	8	3	8	5
		45-60	0	0	4	3	7	3	7	3
		60-100	0	0	3	3	2	3	1	2
		Total	2	2	23	34	27	15	20	17
Vazhuvadi	1977-78	0-15	0	2	0	5	2	3	2	0
		15-30	0	11	14	14	6	9	1	2
		30-45	0	2	5	5	2	5	4	4
		45-60	0	0	5	7	7	6	7	9
		60-100	0	0	11	4	0	3	3	0
		Total	0	15	35	35	17	26	17	15
	1978-79	0-15	0	0	0	0	0	0	4	1
		15-30	2	1	5	3	3	7	4	4
		30-45	3	6	8	2	8	7	0	6
		45-60	1	2	6	3	3	3	1	0
		60-100	1	0	3	0	3	4	9	3
		Total	7	9	22	8	17	21	18	14
	1979-80	0-15	1	1	1	0	1	3	1	1
		15-30	0	0	2	3	5	7	2	1
		30-45	3	6	4	3	8	3	4	2
		45-60	1	3	1	1	8	5	7	4
		60-100	2	1	0	0	2	2	0	2
		Total	7	11	8	7	24	20	14	10

Population given is the total number of grubs in 10 pits.

different depths of soil in different periods of the year.

Feb.		Marc		Apr.		May		Jun.		Jul.		total
a	b	a	b	a	b	a	b	a	b	a	b	
0	1	1	7	3	6	2	4	0	0	0	0	60
0	9	4	21	20	15	7	7	0	0	2	0	181
3	6	6	16	11	10	3	4	2	1	4	0	132
8	7	6	6	3	2	0	5	4	1	4	0	88
4	13	0	1	0	1	0	4	6	0	1	0	44
15	36	17	51	37	34	12	24	12	2	11	0	505
0	2	0	0	0	1	5	0	0	0	0	0	25
1	5	4	4	1	4	11	1	0	1	0	0	72
2	1	8	3	0	1	0	0	3	0	0	0	65
2	3	5	4	0	2	2	1	2	0	0	0	48
9	5	2	8	1	3	1	0	2	0	0	0	46
14	16	19	19	2	11	19	2	7	1	0	0	255
2	2	0	0	0	0	0	0	0	0	0	0	18
1	2	1	1	0	0	3	0	0	0	0	0	47
4	3	1	1	1	3	1	2	1	1	0	0	64
8	5	4	8	11	7	4	1	0	1	00	0	76
2	5	8	2	8	10	0	2	1	1	0	0	53
17	17	14	12	20	20	8	5	2	3	0	0	258
0	1	3	2	0	1	1	0	0	0	0	0	22
3	4	4	7	4	2	8	0	4	0	0	0	93
8	5	7	9	9	5	1	1	5	2	0	0	79
3	1	1	3	0	1	0	1	1	2	0	0	53
1	2	1	7	0	0	0	9	0	0	0	0	41
15	13	16	28	13	9	9	11	10	4	0	0	288
0	2	0	1	1	9	0	1	0	0	0	0	19
2	7	2	2	4	28	3	1	4	2	12	7	103
0	4	5	7	3	3	1	1	7	1	0	0	72
4	4	9	13	1	1	1	2	0	0	0	0	54
2	5	8	5	1	0	0	0	0	0	0	0	44
8	22	24	28	10	41	5	5	11	3	12	7	292
0	0	0	0	0	0	1	0	0	0	0	0	10
0	0	1	0	2	2	1	0	4	0	0	0	30
3	3	8	7	2	4	0	0	5	2	0	0	67
8	3	5	9	4	4	0	1	2	1	0	0	67
3	4	5	3	2	0	0	7	1	2	0	0	36
14	10	19	19	10	10	2	8	12	5	0	0	210

Appendix 6. Distribution of pupae of L. coneophora in different depths of soil in different periods of the year.

location	year	depth (cm)	Mar. a	Mar. b	Apr. a	Apr. b	May a	May b	Jun. a	Jun. b	Jul. a	Jul. b	Aug. a	Aug. b	total
Thazhakkara	1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	0	0	0	0	0	0
		30-45	0	0	0	0	2	0	0	1	0	1	0	0	4
		45-60	0	0	0	0	0	2	0	0	1	0	0	0	3
		60-100	0	0	0	0	5	11	5	0	3	0	0	0	24
		Total	0	0	0	0	7	13	5	1	4	1	0	0	31
	1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	3	0	3	0	0	6
		30-45	0	0	0	1	1	0	0	2	4	0	1	1	10
		45-60	0	0	2	1	0	2	3	1	7	0	1	1	18
		60-100	0	0	0	0	3	1	2	7	0	0	1	0	14
		Total	0	0	2	2	4	3	5	13	11	3	3	2	48
	1980	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	0	0	0	0	0	0
		30-45	0	0	1	1	2	4	2	4	0	1	0	0	15
		45-60	0	0	1	2	2	1	1	3	2	3	0	0	15
		60-100	0	0	2	2	2	0	6	9	7	4	0	0	32
		Total	0	0	4	5	6	5	9	16	9	8	0	0	62
Vazhuvadi	1978	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	1	2	0	0	0	0	0	0	3
		30-45	0	0	0	0	0	3	2	2	1	0	0	0	8
		45-60	0	0	0	0	1	0	7	3	2	0	0	0	13
		60-100	0	0	0	0	3	18	16	5	0	0	2	0	44
		Total	0	0	0	0	5	23	25	10	3	0	2	0	68
	1979	0-15	0	0	0	0	0	0	0	0	0	0	0	0	0
		15-30	0	0	0	0	0	0	0	3	3	3	0	0	9
		30-45	0	0	0	0	1	0	8	5	2	3	0	0	19
		45-60	1	2	0	4	1	2	5	1	0	2	0	0	18
		60-100	0	0	0	0	1	1	9	0	1	0	0	0	12
		Total	1	2	0	4	3	3	22	9	6	8	0	0	58
	1980	0-15	0	0	2	1	0	0	0	0	0	0	0	0	3
		15-30	0	0	2	0	2	0	6	0	0	0	0	0	4
		30-45	2	2	4	3	4	1	2	1	2	1	0	0	22
		45-60	1	2	4	7	1	3	7	4	1	0	0	0	30
		60-100	1	0	10	0	0	0	9	7	1	1	0	0	29
		Total	4	4	22	11	7	4	18	12	4	2	0	0	88

Population given is the total number of papae in 10 pits.
a = first fortnight of the month; b = second fortnight of the month.

Appendix 7. Meteorological data relating to Thazhakkara for the period

year	depth (cm)	January a	January b	February a	February b	March a	March b	April a	April b	May a	May b
					soil temperature °C						
1977	0-15										
	15-30										
	30-45										
	45-60										
1978	0-15	43.0	43.8	44.4	46.3	40.5	38.0	28.3	32.5	39.5	41.6
	15-30	34.0	34.3	34.4	36.9	35.0	38.6	29.2	29.7	35.3	35.3
	30-45	32.4	32.4	33.8	34.8	32.6	36.4	29.4	29.0	33.0	32.5
	45-60	31.5	31.5	33.2	33.0	32.0	34.0	29.0	28.8	31.0	31.0
1979	0-15	39.9	40.2	44.9	43.8	43.0	44.0	43.0	44.4	33.0	27.7
	15-30	33.3	33.7	35.3	36.8	36.9	35.9	37.5	36.6	32.2	26.9
	30-45	31.1	32.4	34.0	34.4	34.4	35.2	36.0	34.8	32.8	32.2
	45-60	30.0	29.2	33.0	32.0	35.6	34.6	34.8	32.6	32.0	34.0
1980	0-15	41.0	40.8	40.0	41.3	46.9	48.8	45.1	39.1	42.5	41.3
	15-30	33.9	32.5	33.9	35.6	36.4	38.1	40.4	35.3	35.0	36.4
	30-45	32.5	31.8	33.0	34.4	39.9	36.2	36.4	34.4	34.0	34.8
	45-60	31.8	31.8	32.0	31.9	34.8	36.3	35.3	32.0	33.0	33.0
					soil moisture % (w/w)						
1977	0-15										
	15-30										
	30-45										
	45-60										
1978	0-15	7.6	3.2	4.7	4.6	5.9	6.9	5.4	4.5	7.4	4.7
	15-30	7.3	6.1	5.8	4.3	6.3	10.1	6.6	7.5	7.2	4.9
	30-45	6.4	8.9	7.2	6.4	7.7	12.2	5.6	7.6	6.5	4.7
	45-60	7.2	8.9	7.7	6.6	8.4	11.3	5.3	6.8	6.3	6.4
1979	0-15	7.5	4.6	6.5	4.0	8.8	5.9	4.9	11.5	10.8	5.8
	15-30	7.5	6.1	6.4	4.8	7.3	5.1	5.3	13.6	11.5	7.3
	30-45	7.2	6.9	6.7	5.5	8.2	7.7	5.9	13.4	14.8	8.6
	45-60	8.3	8.3	8.7	6.2	8.7	8.1	6.6	15.8	16.1	13.2
1980	0-15	3.9	4.4	4.3	3.1	3.0	7.3	7.3	5.2	5.4	4.6
	15-30	4.6	4.9	5.0	5.2	4.0	4.9	5.5	8.0	7.2	5.9
	30-45	7.3	7.8	6.0	5.8	5.6	5.5	4.6	8.7	6.4	7.8
	45-60	5.6	7.3	7.3	6.2	7.2	5.9	5.5	6.5	6.5	7.9
					total rain (mm)						
1977											
1978		0	0	5	18	12	29	42	30	17	231
1979		60	0	0	14	0	24	14	48	14	22
1980		0	0	0	0	8	30	43	19	85	92

a = first fortnight of the month b = second fortnight of the month

from September, 1977 to September, 1980.

June		July		August		September		October		November		December	
a	b	a	b	a	b	a	b	a	b	a	b	a	b
						32.1	42.5	41.1	32.8	39.7	39.2	40.1	41.1
						29.4	36.9	36.2	31.5	34.4	33.0	34.3	35.8
						28.5	33.3	32.3	31.2	30.6	30.4	31.3	29.4
						28.0	30.1	29.5	27.0	29.0	29.1	29.1	28.5
35.5	32.5	32.7	30.8	35.8	33.6	43.0	34.4	41.6	40.8	35.3	39.9	39.4	39.4
31.9	29.7	30.8	29.5	30.5	30.4	32.0	32.2	35.3	32.2	30.8	34.7	34.2	33.6
29.4	29.0	29.6	29.4	28.9	28.4	32.4	30.8	31.8	32.4	30.4	32.4	31.2	32.0
28.5	28.0	28.6	29.0	28.0	27.6	31.0	30.0	30.5	31.0	30.0	31.3	30.5	30.8
43.0	38.3	35.8	37.5	28.9	36.5	40.1	35.2	41.0	37.1	35.8	38.3	37.2	39.8
38.0	33.9	30.8	34.7	28.0	34.7	31.9	33.5	35.5	33.0	33.1	31.4	31.3	34.7
35.0	31.9	31.0	32.4	28.2	32.6	31.1	31.4	32.4	32.5	30.8	31.2	31.2	32.6
34.0	30.4	29.5	30.6	28.6	31.4	31.5	29.3	31.5	31.0	29.4	30.0	30.2	31.1
35.4	35.4	26.1	28.1	30.1	31.9	38.1	37.5						
34.8	32.8	26.9	28.5	31.2	32.0	29.5	35.2						
34.1	32.6	29.4	30.0	31.5	32.5	29.0	30.3						
32.0	32.0	29.4	30.0	31.5	32.5	28.0	29.5						
						9.2	5.9	6.1	8.5	7.8	7.9	4.8	4.7
						9.8	8.1	6.8	7.7	6.8	7.5	5.1	5.4
						10.8	9.9	6.5	8.4	7.4	8.8	5.1	5.4
						12.8	14.9	6.5	9.8	10.6	10.2	6.5	5.8
7.7	10.2	8.3	8.7	11.6	10.3	7.9	6.5	6.3	5.2	5.3	5.4	5.5	3.3
7.2	8.6	7.9	9.2	14.2	9.3	8.5	7.3	7.0	8.1	8.2	6.5	6.4	4.3
6.7	9.9	8.4	12.7	17.7	10.2	9.5	8.8	6.9	8.9	8.9	8.3	7.2	5.9
6.7	10.8	8.9	15.1	17.9	10.1	11.9	12.5	6.8	10.5	16.9	8.3	6.8	7.2
6.2	6.5	9.6	7.6	8.4	10.5	8.8	7.7	5.7	5.0	5.3	5.2	4.3	3.9
7.1	6.8	9.2	9.8	8.8	9.3	9.3	8.1	6.7	6.3	8.2	7.4	7.3	4.5
7.8	8.2	9.8	9.0	11.1	9.2	9.5	9.6	8.1	7.4	8.7	7.3	7.5	5.6
12.1	6.8	12.4	14.4	12.8	14.7	13.7	13.5	11.2	11.5	10.4	8.6	9.4	7.3
6.5	9.0	9.6	9.5	10.5	8.7	7.5	6.5						
5.8	7.6	11.4	10.2	10.8	9.3	8.5	8.4						
7.9	6.5	13.4	10.7	10.9	10.1	8.7	8.9						
7.9	6.9	16.9	10.8	11.3	11.1	11.9	10.4						
						99	106	150	287	249	196	27	29
234	137	250	177	330	129	99	61	27	255	255	362	127	25
272	281	153	139	63	70	144	133	101	28	98	145	74	11
207	321	306	212	179	88	101	110						

Appendix 8. ANOVA relating to:-

Table 1.

source	d.f.	mean sum of squares					
		duration of grub				duration of pupal period	duration of egg to adult
		first instar	second instar	third instar	total		
Male							
Host	3	24.43	403.29**	545.62**	2263.37**	21.02**	2535.20**
Error	36	13.78	45.51	88.11	121.05	2.60	123.61
Female							
Host	3	3.89	694.33**	518.26**	2165.70**	20.49**	2461.09**
Error	36	14.92	42.57	67.30	63.08	4.43	74.48

Table 2.

source	d.f.	mean sum of squares					
		male			female		
		length	width	weight	length	width	weight
Host	3	55.76**	3.36*	0.64	91.75**	2.29**	4.39**
Error	36	6.26	0.86	0.31	2.99	0.64	3.17

Table 3.

source	d.f.	mean sum of squares					
		male			female		
		length	width	weight	length	width	weight
Host	3	28.63**	8.96**	0.52**	65.49**	7.65**	6.46**
Error	36	5.42	1.02	0.08	3.93	1.50	0.31

Appendix 8 (contd...)

Table 4.

source	d.f.	mean sum of squares					
		male			female		
		length	width	weight	length	width	weight
Host	3	20.90**	1.61	0.63**	26.30**	11.89**	2.25**
Error	36	2.67	1.58	0.05	2.60	1.34	1.41

Table 5.

source	d.f.	mean sum of squares				
		male longevity	female longevity	oviposition period	No. of egg laid	percent egg hatched
Host	3	529.49**	43.95*	354.10**	3745.29**	102.82*
Error	36	9.90	5.20	7.52	206.51	23.22

Table 6.

source	d.f.	mean sum of squares						
				No. of new	weight of			
		height	girth	leaves	top growth	roots	damaged tubers	undamaged tubers
Replication	14	1818.34	0.029	155.24	15334.49	16078.75	176955.79	4062609.83
Treatment	3	16993.02**	1.28**	1303.52**	807227.75**	66790.94**	2104567.84**	807277.75**
Error	42	592.13	0.0031	165.75	14912.94	11356.42	126948.33	14912.94

		weight of underground growth
Replication	14	240669.82
Treatment	3	7249754.91**
Error	42	277699.72

Appendix 8 (contd...)

Table 7.

source	d.f.	mean sum of squares			
		starch	amylose	amylopectin	HCN
Treatment	2	849.53**	190.66**	187.51**	581.27**
Error	27	20.47	1.87	1.90	35.58

Table 8.

source	d.f.	mean sum of squares				
		height	new leaves	length of tap root	weight of aboveground growth	weight of underground growth
Replication	14	17.81	1.023	18.99	3.02	2.35
Treatment	3	459.08**	209.51**	980.63**	505.44**	176.10**
Error	42	13.26	0.96	9.10	1.79	1.31

Appendix 8 (contd...)

Table 9.

source	d.f.	mean sum of squares					
		Height	No. of branches	No. of leaves	length of tap root	weight of aboveground growth	weight of underground growth
Replication	14	124.26	25.24	322.41	93.02	42.92	15.02
Treatment	1	41589.63**	2881.20**	188972.03**	39750.25**	13107.64**	10364.66*
Error	14	85.34	11.77	387.58	119.54	83.41	20.97

Table 20.

source	d.f.	mean sum of squares		
		survival of grubs	survival of pupae	mortality of plants
Treatment	8	1514.69**	1022.65**	2306.98**
Error	18	6.92078	7.7565	20.997

BIOLOGY, BIONOMICS AND CONTROL OF COCONUT COCKCHAFER *LEUCOPHOLIS CONEOPHORA* BURM.

By

V. A. ABRAHAM

ABSTRACT OF A THESIS
SUBMITTED IN
PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

Division of Agricultural Entomology
COLLEGE OF AGRICULTURE
Vellayani - Trivandrum

1983

A B S T R A C T

Tho biology of the coconut cockchafer Leucopholis coneophora Burm. was studied in detail for the first time. Techniques for rearing the pests from egg to adult in potted plants kept in field were standardized. The egg laying behaviour of adults was observed. The morphological changes of eggs, different instars of grubs and pupae during development were studied in detail. The changes in immature stages of male and female insects were traced separately. The general morphology of different instars of the grubs was studied in full with a view to finding distinct identifying characters for each.

The external morphology of the adults was examined for identifying suitable characters for the separation of male and female individuals and the nature of antennae in the two sexes was found as an easy and reliable index for separating them.

Adult behaviour of L. coneophora was studied in the field. The emergence of beetles, formation of emergence holes, flight activity of the beetles, mating behaviour and feeding were observed in detail. Adult feeding was studied by providing the beetles with common plants seen in cocoonut gardens, in the laboratory.

Beetles collected from field were dissected and their gut content was examined for studying the consumption of materials, if any. L. coneophora was not found feeding during adult stage.

The studies on the detailed external morphology of the third instar grubs of L. coneophora enabled the development of a taxonomic key for the identification of the three species of Leucopholis prevalent in Kerala viz. L. coneophora, L. burmeisteri and L. lepidophora.

The effect of four different host plants viz. cassava, coconut, cacao and wild sunn-hemp (crotalaria) on the biology and development of L. coneophora was studied in detail. The effect on duration of life stages, body length, width and weight, survival of immature stages, preoviposition period and fecundity were studied and it was observed that the larval nutrition had significant effect on all the above aspects. Cassava and cocconut were found more favourable for the pest than cacao and crotalaria.

The extent and nature of damage done by L. coneophora to the above host plants (except in the case of cocconut) was studied by exposing the plants to different levels of grub population in pots. Cassava was found to be more susceptible at the time of planting and during early stages of growth. When released on four-month-old crop

even a heavy population of five grubs per plant did not kill them outright. The tubers when partly damaged suffered a reduction in the desirable qualities for consumption. Cacao and crotalaria were highly susceptible. Even a low population of one grub per plant caused drastic reduction in the growth of plants and sometimes resulted in the death of the plants. In seedling stages coconut sometimes got killed by the infestation of L. coneophora. Grown up plantations subjected to the infestation of pest, continuously for years, showed severe symptoms and drastic reduction in yield.

The distribution of the different life stages of L. coneophora in different depths of soil was studied at two locations in the infested belt over a period of three years adopting suitable techniques. The distribution of beetles, eggs, three instars of grubs and pupae in different depths over different seasons of the year was studied. The numbers of adults seen in different soil temperature and soil moisture ranges were also observed to assess the preference of zones, if any. Adult emergence and factors influencing the same also were studied.

The bioefficacy of four chlorinated hydrocarbon insecticides against the second and third instar grubs of L. coneophora was assessed by adopting precise bioassay

techniques and the relative toxicity was in the following descending order for the former aldrin > heptachlor > BHC > chlordane and heptachlor > aldrin > BHC > chlordane for the latter.

The relative efficacy of BHC and heptachlor chosen from the above experiment was further evaluated in a field experiment (applied in tube) in different schedules to fix the best time of application for controlling the pest. Single application of heptachlor in June or two applications of BHC in June and September gave complete control of the pest. Application of pesticides in April was found to be less effective.

Persistence of BHC and heptachlor under field condition was studied by assessing the quantity of insecticides in the soil samples collected at different intervals after treatment. Half lives of the insecticides applied in different months also were assessed. The persistence was not as long as it was reported by earlier workers from outside Kerala. The downward movement of the pesticides was also studied by assessing the insecticide content of soil samples from treated plots collected from different depths. Slight infiltration from 15 cm to 45 cm depths was observed but the extent of residue content was not adequate to cause mortality of L. coneophora grubs. This indicated the desirability of raking insecticides applied in field below the usual level of 15 cm.