

**STUDIES ON ARECANUT ROOT GRUB, *Leucopholis lepidophora* Blanch.
AND ITS MANAGEMENT BY ENTOMOPATHOGENIC FUNGI AND PLANT
PRODUCTS**

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1. INTRODUCTION

Arecanut (*Areca catechu* L.) name "areca" was derived from Malayan word meaning 'Cluster of nuts'. Taxonomically, this tree belongs to family *palmae* under the tribe *Arecae* and genus *Areca* which contain 76 species among which *Areca catechu* L. is the only cultivated species. Cultivation of Arecanut is concentrated in South Western and North Eastern regions (up to an elevation of 1000 MSL) of our country. Arecanut has a gestation period of about six years and holds promise in the long run. The crop does well in loamy soils in humid tropics with evenly distributed rainfall. Though, the initial expenses of raising a plantation are high, the returns after the sixth or seventh year will prove it a worthwhile venture. The crop allows a host of intercrops initially, and the returns from the intercrops can meet farm expenses during gestation period.

Arecanut or betelnut mainly used for masticatory purpose and as a consecratory product in several religious ceremonies. Apart from that arecanut is being used in ayurvedic medicines. The medicinal properties of arecanut were known to Vagbhata as early as 4th century A.D. He made use to treat against leucoderma, leprosy, cough, epilepsy, and along with citrus as an anti helmenthic agent etc. Bhavamista (13th century A.D.) has used it as appetizer and stimulant (Watt, 1889).

Consumption of arecanut is steadily increasing from 0.114 million tonnes during 1956-57 to 0.336 million tonnes during 1999-2000. The projected demand of arecanut by 2020 is estimated to be 0.617 million tonnes. The per capita availability of arecanut in India is 1.58 gram per adult per day.

According to Food and Agriculture Organization, the current production of Arecanut in the world is about 0.593 million tonnes from an area of 0.468 million hectares. India ranks first in both area (57%) and production (53%). Among different states, Karnataka is the major arecanut producing state in India, it grows in an area of 119.1 thousand ha (Uttara Kannada 37.5%, Dakshina Kannada 35%, Shimoga 15% and Chikmagalur 12.5%) and more than two lakh farmer families are involved in the arecanut production. Arecanut could provide an assured employment to the extent of one crore man days annually. The direct and indirect revenue to the state government exchequer amounted to roughly Rs. 200 crores (Rethinam and Sivaraman, 2001).

Arecanut is attacked by an array of insect and non-insect pests. The pests infest all parts of the palm viz., stem, leaves, inflorescence, root and nuts. Brown bug *Saissetia hemisphaericum* Targ was the first record as a pest of arecanut by Coleman and Rao (1918). Since then about 102 insect and non-insect pests have been reported to be associated with arecanut palm (Nair and Daniel, 1982), among which few causes considerable economic loss to the crop.

Root grubs belonging to the family Scarabaeidae of Order Coleoptera are considered as "National Pests" are also called white grubs. Out of 1500 species recorded from India, 40 species are reported to be serious pests on economically important Agricultural and Horticultural crops in different parts of the country.

Arecanut mainly suffer from root grub in Western Ghats and 'malnad' belt of Karnataka which include three main species *Leucopholis lepidophora* Blanch, *Leucopholis coneophora* Burn, *Leucopholis burmeisteri* Brenske commonly encountered, damaging coconut and arecanut palm, these cause damage to the root by direct feeding resulting in symptoms like yellowing of leaves, stem tapering, nut fall and ultimately leads to reduced vigour and yield. In two districts, Uttara Kannada and Shimoga there is a considerable loss due to root grubs in arecanut yield. However there is no information available on the population density, extent of yield and species damaging.

To combat this pest usually insecticides are recommended, prolonged dumping of chemical not only causes soil pollution but also has deleterious effect on soil fauna and flora. Hence, a study was undertaken to find out information on yield loss, population density, species available and evaluation of environment friendly approaches with entomopathogens and plant products against the arecanut root grub with following objectives.

1. Survey of root grub infested arecanut gardens in Uttara Kannada and Shimoga districts.
2. Estimation of yield loss in arecanut due to root grub infestation.
3. Evaluation of entomopathogens and plant products against arecanut root grub both in laboratory and field condition.

2. REVIEW OF LITERATURE

A literature search was undertaken to review the information pertaining to root grub pests of crops in India in general and those of arecanut in particular. The relevant information is presented in the following pages under different headings.

Nair and Daniel (1982) reported arecanut palm is attacked by an array of insect and non-insect pests which figured up to 102 in South India, among which spindle bug (*Carvalhoia arecae* Miller and China), 2 species of mites (*Oligonychus indicus* Hirst and *Raoiella indica* Hirst), inflorescence caterpillar (*Tirathaba mundella* Walker), root grubs (*Leucopholis* spp.) and five groups of vertebrate pests were rated as major pests.

2.1 ROOT GRUB AS A PEST OF ARECANUT AND OTHER CROPS IN INDIA

Many species of white grubs are well known pests of a number of cultivated crops in India. They belong to four sub families of Scarabaeidae viz., Dynastinae, Cetoninae, Rutelinae and Melolonthinae, which include all the phytophagous species of the family (Balasimha and Rajagopal, 2003). A detailed review of the known pestiferous species of white grubs in India was provided by Veeresh (1983) and Yadava and Sharma (1995). Therefore the present review is restricted to the members of the subfamily melolonthinae as this subfamily includes the genus *Leucopholis*.

Puttarudraiah and Channabasavanna (1957) were the first to report *Leucopholis lepidophora* Blanchard as an important pest of arecanut from Karnataka. Following their work, Rao *et al.* (1961) recorded *Lepidiota Kirby* as causing damage to the roots of arecanut.

Leucopholis burmeisteri Brenske was later reported as a pest of arecanut (Anonymous, 1967). This was further substantiated by Nair and Daniel in 1982 and stated that *L. burmeisteri* as the most common species affecting arecanut in Dakshina Kannada district of Karnataka.

Veeresh *et al.* (1982) reported three species of *Leucopholis* as the most important white grubs that affect arecanut and coconut in Karnataka.

L. burmeisteri is the major pest of arecanut palm in Karnataka and Kerala, India causing significant yield loss (Padmanaban and Daniel, 2003).

At the same time, since from 1952, a number of publications have declared *L. coneophora* Burmeisteri as the only species that affect coconut from the coastal areas of Kerala (Nirula *et al.*, 1952; Nirula, 1955; 1958; Sekhar, 1958; Veeresh, 1977; Abraham and Kurian, 1970; Nair and Devashyam, 1982). Thus, the species of *Leucopholis* were the most important species of white grubs that attack arecanut and coconut in peninsular India.

2.2 SURVEY FOR THE INFESTATION OF ROOT GRUB ON ARECANUT

2.2.1 Population density of root grub

Stages in the life cycle of the scarabaeid *L. lepidophora* were counted in soil samples taken twice a month in cultivated land in Maharashtra during 1985-87 (which was important pest of sugarcane in India). All the stages were present in August. Eggs were found in August-October, 1st instar larvae in October-February and pupae and adults in June-October. Since 2nd and 3rd instar larvae are the only damaging stages and these were observed in February to June and this period appeared to be the most suitable for control measures, which coincides with cultural operations that were undertaken (Patil and Adsule, 1991).

Survey conducted by Mishra and Singh (1991) in Uttar Pradesh, India during May-September 1991 indicated that eggs and 1st instar larvae were found during June-July, with 2nd and 3rd instar larvae damaging potato tubers found at the end of July and mid August respectively. Larvae migrated downwards in the soil at the end of October and overwintered in a quiescent state. Pupation occurred at a depth of 20 to 30 cm during April.

A sampling technique was standardized by Mohan *et al.* (1997) for the estimation of populations of *L. coneophora* around the palm basin in irrigated coconut gardens in India. The total number of larvae present in the root zone of a palm can be estimated by the regression equation $Y=3.78 + 1.7938 x$, where Y is the total population of larvae found around a palm and X is the number of insect stages found up to a depth of 40 cm at a distance of 50-100 cm away from the trunk of the palm.

The life history of the white grub, *Dasylepida* spp. was surveyed in a sugarcane field in Miyako Island, Okinawa, Japan. Adult flights were observed from early February to mid March in 2000. Adults commenced flight just after sunset (at around 18.30 h) and mated. Sampling from the pots placed in the field on 19 April yielded 41.8 per cent eggs and 58.2 per cent first stadium. Larvae sampled on 20th June 2001 consisted 33.3 and 66.7 per cent first and second stadium larvae, respectively, on 22nd August, 87.5 per cent of larvae were at second stadium and the remainder (12.5%) were third stadium. The proportion of third stadium larvae increased and attained 100 per cent by 30th November. In an excavation survey on 26th November 2001, eleven adults (3 females and 8 males) and 5 pupae were found in the soil at a depth of around 45 cm. These facts indicated that *Dasylepida* spp. has a 2-year life cycle (Oyafuso *et al.*, 2002).

Soil sampling for white grubs in Shimla hills by Chandel *et al.* (2003) revealed high population of *Brahmina coriacea* (Hope) representing of all stages. Pupae were found in the soil during April, adults and eggs in May and June-July, respectively. The larvae were in the soil from July-April. Third instar grubs caused damage through out September-October and over wintered in earthen cell up to April. Adult emergence begins in May, maximum being in mid June.

Padmanaban and Daniel (2003) studied spatial and seasonal distribution of *Leucopholis burmeisteri*, the first instar grubs noticed in the soil up to 2nd week of September, second instar grubs up to December 2nd week where as third instar grubs found up to March.

Survey conducted by Channakeshava (2006) in root grub menace areas of Shimoga shown that the average number of eggs varied from 3.29 to 26.88 per cubic meter of soil during August to September. The average number of first instar grubs varied from 2.65 to 28.67 per cubic meter during August to December. The mean number of second instar grubs varied between zero and 21.28 per cubic meter during August to December. The mean third instar population varied between 1.36 and 23.22 per cent cubic meter during May to October.

2.2.2 Depth of larval availability in arecanut ecosystem

Monthly surveys were conducted by Nigam and Awasthi (1978) at Manipur on larval, pupal and adult populations of *Holotrichia consanguinea* (Blanch) at various soil depths. There was one generation a year. The pest occurred only in sandy soil and over wintered and aestivated (November-May) as the adult, being active only with the onset of rainfall in May-June. When inactive, the adults were commonly found at a depth of 30-70 cm, depending on the soil moisture content. Larvae were found at 0-75 cm from May to October and pupae at 25-10 cm from October to January.

Kumar (1997) reported that eggs of *Leucopholis lepidophora* was observed 15-90 cm below the soil surface. Whereas I, II and III instar larvae were found at 0-80, 10-80 and 0-90 cm depth below the soil surface, respectively. Pupae and teneral adults were found at 30-130 cm depth below the soil surface. Depth of availability of all stages, dependent on soil moisture content of the garden.

2.2.3 Influence of rain fall on root grub population

Veeresh (1977) reported that low and high moisture content in the soil affected the growth, development and movement of the grubs *Holotrichia serrata*. Saturated soil moisture was required for emergence of beetles.

Yadava and Saxena (1977) revealed that sufficient rain (moisture) was required for emergence of beetles. Drought during monsoon season caused the death of beetle in the soil itself.

Veeresh *et al.* (1982) reported that suitable soil moisture increased the grub activity in soil. Stagnation of water in the field reduced the grub population. High moisture content caused rotting of eggs and death of grubs due to suffocation.

Yadava (1991) reported that stagnation of water in the field increased the grub mortality in the soil. Optimum moisture content in soil increased the grub movement and migration.

Mishra and Singh (1993) found that low moisture caused movement of the grub into deeper layer of soil and it also affected the pupation and beetle emergence.

Gupta and Yadava (1993) revealed that optimum soil moisture increased the survival percentage of grubs whereas high soil moisture caused mortality of grubs.

Kumar (1997) reported that *Leucopholis lepidophora* tend to be closer to the surface during the monsoon and deeper during other times. Movement to deeper layers may ensure availability of soil moisture until emergence of adult.

2.2.4 Studies on species identification of root grub

Leucopholis burmeisteri and *L. lepidophora* are the major pests of arecanut. Widely distributed in Kerala and Western Ghats of Karnataka (Veeresh *et al.*, 1982).

Mathur *et al.* (1989) made an extensive survey of Scarabaeidae in Uttar Pradesh, India and recorded twelve species were first recorded from the state for the first time. The beetles were found feeding on a variety of plant species, some being of economic importance.

Phytophagous scarabaeids were collected in ultraviolet-light traps operated at 2 sites in 1998 and 4 sites in 1989 in Georgia, USA. Over 60,000 adults were captured and identified, representing 31 species in 8 genera. Adults of the genus *Cyclocephala* were the most numerous (n>32,000). The genus with the most species was *Phyllophaga* with 22 species collected. However, these *Phyllophaga* collections represented only 4 per cent of total numbers collected at the 4 sites in 1989. The genera *Ligyryus*, *Eutheola* and *Dyscinetus* exhibited the longest flight periods extending from March to October. These survey data illustrate the diversity of the phytophagous Scarabaeidae in Georgia and the need for identification of white grub infestations to genus or species level in order to maximize management efforts (Forschler and Gardner, 1991).

Fourteen species of Scarabaeids were trapped in light traps in Kumaon, Uttar Pradesh, India during 1995 and 1996 of which *Anomala dimidiata* B. was the predominant one (Mishra and Singh, 1993).

Jitender Kumar *et al.* (1996) reported 16 species of defoliating beetles were encountered in 1992 and 1993 by light trap studies in Himachal Pradesh. Among these, three species belong to *Anomala*, two each to *Brahmina*, *Phyllognathus* and *Apongonia*, one each to *Maladera*, *Holotrichia* and *Adoratus* and four unidentified species. *Brahmina crinicolis* Bermeister and *Maladera insanibilis* Brenske comprising 18.87 and 29.58 per cent of the total population and they were predominant during 1992 and 1993, respectively, *Holotrichia longipennis* Blanchard and *Anomala dimidiata* Hope were the least abundant beetles during the respective years.

Chandel *et al.* (1997) reported 21 species of defoliating beetles on apple, pear, plum and apricot in Himachal Pradesh during 1990 and 1991. *Brahmina coriacea* Hope, *Holotrichia seticollis* F. and *Holotrichia longipennis* Blanch were the predominant species constituting 42.5 to 51.7, 14.3 to 20.1 and 8.2 to 19.9 per cent of total catch during 1990 and 1991, respectively.

Kumar (1997) reported *Leucopholis lepidophora* was found distributed throughout the hilly areas covering Uttara Kannada, Dakshina Kannada, Shimoga, Chikmagalur districts of the state. This accounts for 58.3 per cent of total area visited and 88.15 per cent arecanut gardens were infested with white grubs.

The two white grub species *Dasylepida* spp. and *Anomala albopilosa* Satishmana were found to infest the roots of sugarcane severely and caused blighted stalks in Miyako Islands, Japan. This is the first record that the larvae of *Dasylepida* spp. caused damage to

sugarcane. The third instar larvae of *Dasylepida* sp. is smaller in head width and has a whiter body than those of the third instar larvae of *Anomala albopilosa* Satishmana. When these 2 species of larvae were exposed to the surface, *Anomala albopilosa* Satishmana immediately borrowed into the ground while *Dasylepida* sp. larvae were extremely sluggish and unable to dig into ground. The mean number of larvae of *Dasylepida* sp. on damaged stools was significantly higher than of *Anomala albopilosa* Satishmana. In Miyako Island, the larvae of *Anomala albopilosa* Satishmana were found extensively from interior to the coastal areas, whereas the occurrence of *Dasylepida* sp. larvae was restricted to the interior areas where damaged fields are frequently found (Sadoyama *et al.*, 2001).

Singh and Mishra (2003) recorded the white grubs belonging to eight sub families distributed over 15 host plants in Uttaranchal hills. An extensive survey of white grubs menace areas in Uttaranchal showed that, five major species of scarabaeid beetles *viz.*, *Holotrichia longipennis* Blanch, *Holotrichia setiocolis* Moser, *Anomala dimidiata* Hope, *Anomala leueatopennis* Blanch and *Brahmina coriacea* Hope caused the severe damage on various crops.

2.2.5 Natural enemies of arecanut root grub

A study was undertaken by Kumar (1997) to record the natural enemies of arecanut root grub showed the predators like wild boar (*Sus cristatus*), two species of crows and a species of bat, among the parasitoids, scoliids and Bombyliids were found to parasitise the grubs. Among the entomopathogens, *Metarrhizium anisopliae*, *Bacillus popilliae*, *Beauveria brongniartii* and nematodes like *Steinernema glaseri* and *Heterorhabditis* sp. are the major ones.

A survey was undertaken by Padmanaban *et al.* (2003) in arecanut root grub endemic areas to record the natural enemies of white grub. They found, Bacteria (*Myrothecium* and *Bacillus*), fungi (*Aspergillus flavus*, *Metarrhizium* sp., *Fusarium* sp.), protozoa (*Pseudomonocystis* sp.), nematodes (*Steinernematid* and *Heterorhabditis*), Hymenopteran parasitoids (Scoliid wasps), Dipteran parasitoid (Bombyliids) and Aver (common crow and bat) as the major natural enemies.

2.3 ESTIMATION OF YIELD LOSS DUE TO ROOT GRUB

Sugarcane white grubs (Coleoptera: Scarabaeidae) feed on roots causing lodging, reduced plant growth and death of the cane. This holds 75 per cent share among all insect pest losses to sugarcane in Australia (Anonymous, 1990).

Survey of the Scarabaeids, *Leucopholis* spp. in arecanut plantation conducted by Gowda *et al.* (1990) revealed that grub infestation results in average reduction in yield, which was estimated to be 101.12 kg/acre under severe infestation.

Mishra (1995) reported, out of several species of white grub damaging potatoes, *Holotrichia coracea* (Hope) is the predominant species in North-western hills of Himachal Pradesh. The damage or yield reduction in potato tubers ranged from 15.5 to 80.0 per cent (based on the weight of total and damaged potatoes) in prone areas. The maximum damage (80.0%) was recorded in Shilaroo and its adjoining villages and least (15.5%) in Shimla. Also, 50.9 per cent damage to potatoes was recorded from Sirmour district. Late harvested crop suffered the most.

Arecanut white grub, *L. burmeisteri* Brenske is the major pest of arecanut palms in Karnataka and Kerala causing significant yield loss. Grub feeds on root results in yellowing of leaves and stem tapering. Stem tapering in relation to yield can be correlated to know the yield loss from initial infestation of root grub (Padmanaban and Daniel, 2003).

2.4 MANAGEMENT OF ARECANUT WHITE GRUB BY BIO AGENTS AND PLANT PRODUCTS

2.4.1 Entomopathogenic fungi, *Metarrhizium anisopliae* (Met.) Sorkin and *Beauveria brongniartii*

In a laboratory study, the fungus, *Metarrhizium anisopliae* when used at higher doses (7.98×10^7 conidia/g) caused 90 per cent mortality of *H. consanguinea* seven days after treatment (Patel *et al.*, 1986).

Milner (1990) reported that, two isolates of *M. anisopliae* viz., FI-147 and FI-153, were effective against a range of hosts belonging to *Antitrogus* spp. and *Lepidiota* spp., while FI-114 was particularly effective against *A. parvulus*. The LC₅₀ of these strains against their target hosts were between 1×10^4 and 5×10^4 conidia per gram of soil.

Braza (1990) tested two strains of the entomogenous fungus *M. anisopliae* against the scarabaeids, *L. irrorata* in the laboratory. When applied as conidia on infected palay, mixed with sawdust @ 5 g mixture/larvae, the strain MA WG and MaOR caused 73 and 3 per cent mortality of *L. irrorata*, respectively.

Krueger *et al.* (1992) studied the efficacy of soil application of *M. anisopliae* conidia and lyophilized mycelial particles against scarabaeid grubs. The grub mortality occurred significantly quicker in mycelial inoculated soil. Total mortality however did not differ significantly between the two inoculums. Liquid culture of *M. anisopliae* can be induced to form aggregates of hyphal cells under certain conditions.

Gupta *et al.* (1998) evaluated the virulence of four isolates of both *M. anisopliae* and *Beauveria bassiana* and two isolates of *B. brongniartii* against late second or third instar grubs of *H. consanguinea* and *Maladera insanabilis*. Among the *Metarrhizium* isolates, Ma-4 was proved to be most virulent exhibiting cent per cent mortality on fourth day of inoculation followed by Ma-3, Ma-1 and Ma-2 requiring 6, 9 and 10 days, respectively, to cause cent per cent mortality of *H. consanguinea*. Similarly Ma-4 isolate was found better against *M. insanabilis* which took only 3 days to cause cent per cent mortality as against 5 to 6 days in remaining isolates (Ma-1, Ma-2 and Ma-3).

Samson *et al.* (1999) found that, the numbers of white grubs (*Dermolepida* spp.) on sugarcane were consistently reduced by more than 50 per cent when spores of *M. anisopliae* (FI-1045) together with rice medium were applied @ 33 kg per ha. On the other hand, a granulated formation of *M. anisopliae* (ZBW 9501) when applied @ 8.2×10^{12} conidia/ha had no major impact on the pest and it was concluded that, the poor efficacy of fungus in field mainly because of poor virulence and poor epizootic potentiality of the isolate (mazodze and Zvoutete).

Median lethal time (LT₅₀) values for first, second and third instars of *H. consanguinea* were 5.87, 8.30 and 6.20 days, respectively, when exposed to 4×10^7 conidia/g of *Metarrhizium anisopliae* applied to soil. Similar response was noted when the fungus was tested against *M. insanabilis* instars (Sharma *et al.*, 1999).

When *Metarrhizium anisopliae* var. *anisopliae* tested against third instar larvae of cane grubs and recorded LC₅₀ value of *M. anisopliae* @ 8.7×10^4 conidia per gram peat substrate ten weeks after inoculum. The dose of 1×10^6 conidia per g peat killed 96 per cent cane grubs (*Antitrogus* spp.), 85 per cent of *Lepidiota* spp. and less than 36 per cent of other five species of cane grubs tested (Milner *et al.*, 2002).

Padmanaban *et al.* (2003) reported that natural incidence of *Metarrhizium* spp. and other entomopathogenic fungus on 1st, 2nd, 3rd and pre pupae of *Leucopholis burmeisteri* and *L. coneophora* of white grub endemic areas in Kerala.

Field efficacy of talc based conidial formulation of *M. anisopliae* and *B. bassiana* was evaluated against white grub (*Brahmina* sp.) by Bhagat *et al.* (2003) in potato. Treatment comprised, *M. anisopliae* (5×10^{13}), *Beauveria bassiana* (5×10^{13}), chlorpyrifos (200 to 400 g/ha) alone or in combination. *M. anisopliae* formation applied at 5×10^{13} conidia/ha along with chlorpyrifos 20 EC at 200 g a.i./ha was effective in controlling the grub population (56.5%), exhibiting maximum reduction in plant mortality (75-80%) and tuber damage (63.7%), which resulted in the highest tuber yield (155 t/ha).

A field experiment was conducted by Chirame *et al.* (2003) in Maharashtra, India. To study the efficacy of *B. brongniartii* against white grub (*Holotrichia serrata*) infesting sugarcane. The spores of *B. brongniartii* were applied at 10^9 spores/ml. The treated plots showed 2.5 per cent crop damage, 1.5 white grub larvae per meter of row length and a yield

of 19 t/ha. The untreated plots showed 74 per cent crop damage, 36 white grub larvae per meter of row length and a yield of 23 t/ha.

Field evaluation of *M. anisopliae* (Ma-1) against arecanut root grub (*Leucopholis lepidophora*) revealed that, mycopathogen @ 2×10^{13} conidia/ha recorded 60.06 per cent reduction in grub population and was next best to chlorpyrifos 20 EC drenching @ 5 l/ha (Hajeri, 2003).

Rachappa *et al.* (2004) reported that *M. anisopliae* isolate Ma-2 conidia @ 1×10^{13} , 7.5×10^{12} , 5×10^{12} / ha were compared with chlorpyrifos @ 5 litre, phorate 25 kg and neem cake 500 kg/ha. Among different dosages of *M. anisopliae* evaluated against sugarcane root grub at Sankeshwar, Karnataka the higher dosage of *M. anisopliae* @ 1×10^{13} conidia per ha was found as effective as chlorpyrifos.

Field trial conducted by Channakeshava (2006) in arecanut garden near Sagara and Shimoga in Karnataka state, against root grub (*Leucopholis lepidophora*) showed *M. anisopliae* 2×10^8 conidia/g @ 1.1 kg per acre given 50.97 per cent mortality which is significantly differ with neem cake @ 550 kg per acre which gave only 14.21 per cent mortality.

2.4.2 Evaluation of Strychnine and Soap nut against arecanut root grub

There is no literature available pertaining to efficacy of Strychnine and soap nut against root grub, hence it is the first debut. So reviews of some of the other plant products and oil cakes against root grub are furnished here.

Kumar and Daniel (1981) reported that *L. burmeisteri* infesting arecanut roots can be managed effectively by using dimethoate 5 per cent granules at 30 kg/ha. Pongamia oil cake at 2000 kg/ha, chlordane 5 per cent dust at 90 and 120 kg/ha and quinalphos 1.5 per cent dust at 90 and 120 kg/ha.

Field evaluation of neem cake @ 1000 kg/ha against arecanut root grub *L. lepidophora* caused a mean reduction of 21 and 34 per cent during I and II year trial in Sringeri, Karnataka state (Subaharan *et al.*, 1997).

In a trial at Vittal, Karnataka, during 1992-93, the commercially available oil cakes neem, Karanj (*Pongamia pinnata*) and Mahua (*Madhuca longifolia*) were applied to pots containing 2 year old arecanut seedlings grown in sterile soil with 10 third instar *L. burmeisteri* grubs at rates equivalent to 1000, 1500, 2000 and 2500 kg/ha. In a second trial during 1993-94, 250 ml of vitoxyl (2%), nimbecidine (2%) and ahook (2%) and 85 g of fresh, and dried and powdered leaves of *Vitex negundo* were applied to pots containing second instar grubs. Grub mortality was recorded 30 days after treatment. Of the oil cakes, Karanj gave the highest mortality. Among the plant products, leaf powder of *V. negundo* recorded highest mortality followed by Ahook (Padmanaban *et al.*, 1997).

3. MATERIAL AND METHODS

Arecanut is a major commercial plantation crop in Uttara Kannada and Shimoga districts. Sirsi, Siddapura and Yellapura taluks of Uttara Kannada and Sagara and Thirthahalli taluks of Shimoga district were selected for the studies on arecanut root grub. Surveys were made in these taluks of two districts to get information on root grub activity, population density, extent of damage and species found. During the survey, about 100 field visits were made periodically in four rounds to select every two months. Survey was also done for a suitable garden for conducting field trials on root grub management. A proforma was prepared to collect relevant information during the survey after interacting with the farmers (Appendix 1). Root grub samples from five taluks were collected during the survey and sent for taxonomic identification of species by an expert. Late instar root grub were collected during the survey, for use in laboratory for management studies. Laboratory studies were conducted at both Agricultural research station, Sirsi and College of Agriculture, Dharwad. Field trials were conducted in arecanut garden in a village called Mavinakoppa, which is 12 km from Sirsi.

3.1 ARECANUT ECOSYSTEM

Arecanut ecosystem comprised Arecanut as main crop along with banana, vanilla, cocoa, pepper and cardamom as inter crops. In five taluks of two districts which come under classification of zone 9 which is a hilly zone lying in Western Ghats of Karnataka.

Gardens in these taluks are of varying age level including gardens which are converted from paddy fields with new plantations of 5 years old and also older gardens of about 60 years. The gardens had varied level of drainage system, varied spacing and varied level of management by farmers. Most of the gardens were converted paddy fields into arecanut plantations. Gardens mainly depended on rain water but also irrigation system seen in few gardens with drip irrigation, flooding and occasionally micro irrigation.

3.2 SURVEYS FOR ROOT GRUB INFESTED GARDENS

A roving survey was conducted in the selected taluks of Uttara Kannada and Shimoga districts where arecanut is grown extensively. Selected five taluks include Sirsi, Siddapura, Yellapura, Sagara and Thirthahalli. Surveys were made in four rounds periodically starting from August 2006 to March 2007. In each taluk five different villages were selected representing the taluk. The villages visited are listed in tables 2, 3, 4 and 5. In each garden, samples were collected from randomly selected five trees. Trees are dugged all-around with varying depth depending on moisture level of the garden. Soil was removed in about two feet radius around the arecanut tree in the root zone. Sampling was done to observe different stages of root grubs and number of each stages was recorded. Other relevant information like farmers name and address, area of garden, garden history age, previous crop, inter crop, other problems, control measures under taken and damage symptoms observed were recorded in the proforma.

During the sampling, different stages of root grubs were collected for the further studies in laboratory including species identification of species and management studies with different bioagents, botanical and insecticides. The collected different stages of root grub were observed for the natural enemies including parasites, predators and pathogens if any (Plate 1).

3.3 SELECTION OF GARDEN FOR FIELD TRIALS

For conducting field trials, one arecanut garden was selected in a village called Mavinakoppa which is 12 km from Agricultural Research Station, Sirsi. Selected garden was spread in an area of 3.5 acre, trees are about 18 year old and root grub problem was prevailing in the garden for last seven years.

3.4 ESTIMATION OF YIELD LOSS IN ARECANUT DUE TO ROOT GRUB INFESTATION



Soil opened for observation of different stages of arecanut root grub



The digging tool used in the sampling of root grub stages



Arecanut garden adjacent to paddy field



Old and traditional garden



Cluster of adults in mating position in arecanut plantations



Mating pair of *Leucopholis lepidophora*



Collection of data with arecanut farmers regarding on root grub management



Collection of late instar larva of arecanut root grub for species identification and lab study

Plate 1. Photographs showing sampling of root grub population during the survey in different taluks of Uttara Kannada and Shimoga districts

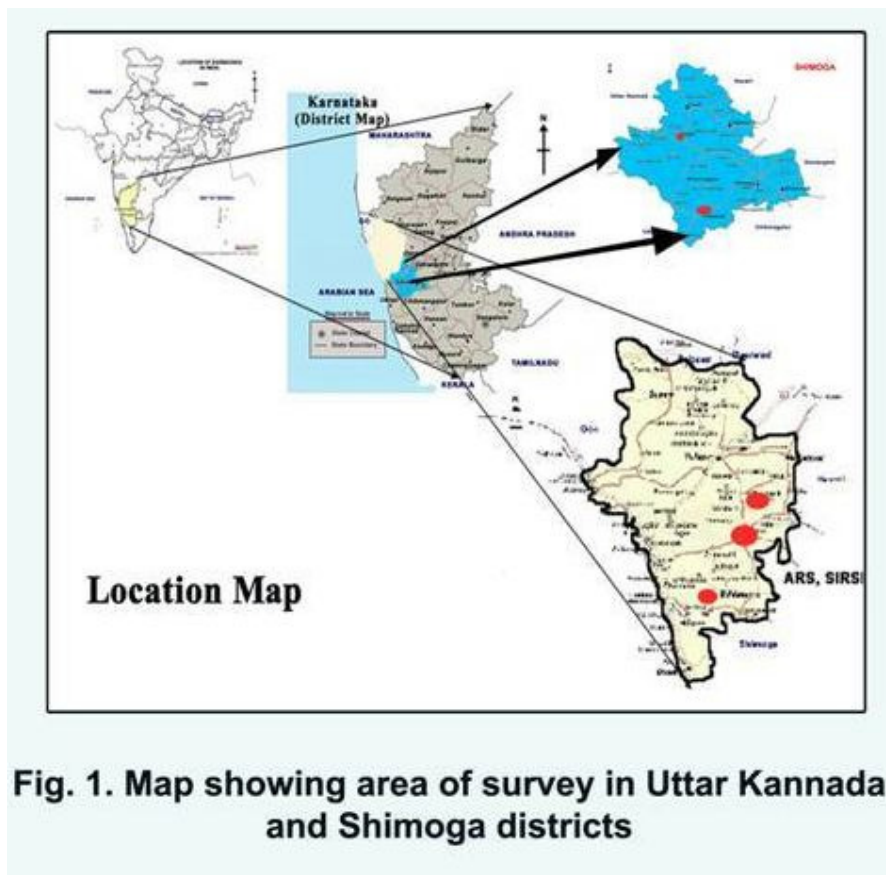


Fig. 1. Map showing area of survey in Uttar Kannada and Shimoga districts

Fig 1. Map showing area of survey in Uttar Kannada and Shimoga districts

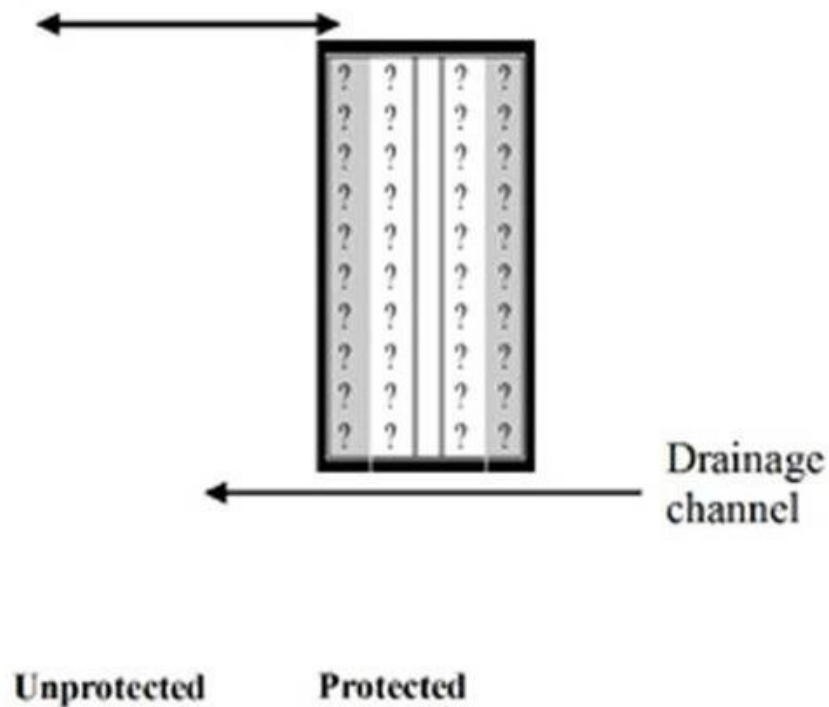


Fig. 2: Experimental lay out for yield loss estimation for arecanut root L. lepidophora (Shaded rows are selected for trial)

Fig 2. Experimental lay out for yield loss estimation for arecanut root grub, *L. lepidophora* (Shaded rows are selected for trail)

A separate study was conducted for the estimation of yield loss in arecanut due to root grub infestation for one season. Two sets of trees were selected and maintained under completely protected and unprotected condition. For this ten trees were numbered in a row for protected block and ten trees in a next row were numbered for unprotected block. These blocks were separated with a distance of 20 feet (Fig.2).

For trees in the unprotected block no control measures were taken, only grub counts were taken around each tree, up to end of the season.

In protected block, after taking the grub count, grubs were removed mechanically by digging. Further, a recommended insecticide, chlorpyrifos 20EC was applied to the base of each tree with a concentration of 3 ml per litre of water. Each tree consumed about two litres of such solution. Further, in protected block, root grubs were removed mechanically after every 30 days intervals and chlorpyrifos 20EC was applied at root zone in the soil as said earlier. Observation on the nut yield on wet basis was taken in the experimental blocks.

Yield data in protected and unprotected blocks was subjected for statistical analysis by conducting independent sample "t" test.

3.5 IDENTIFICATION OF ROOT GRUB SPECIES AND THEIR NATURAL ENEMIES IN THE STUDY AREA

During the survey in five taluks, matured third instar root grub larvae were collected and brought for the identification. Larval specimens were packed in perforated plastic vials of 5X3.5 cm along with potato pieces for feeding. A wet tissue paper was kept inside to avoid desiccation during transit. Dead root grub larvae were also sent for the presence of any insect pathogens. These samples were sent to root grub specialist, Dr. A.R.V Kumar, Associate professor, AICRP on white grubs, UAS Bangalore for identification. Following keys were used for *Leucopholis* sp.

Keys to the III instar larvae of *Leucopholis* sp.

Maxillary stridulatory teeth 15-17 and arranged in a clear longitudinal line palidia on the raster, separated by less than twice the length of the pali. Pali roundish, not very strongly sclerotised.

Adult characters

Body uniformly black, external surface of the body uniformly covered with subovate, creamy white adpressed scales. Scales with a slight apical projection. Pygidium broader than long and broadly triangular.

Metasternal spine smooth, apex roundish and slightly raised above the surface. Prosternal process slightly raised, sub-rectangular, surface smooth interspersed with few scales and hairs.

Females: Larger than males on an average. Antennal club 1 times the length of first antennal segment. Hind tibial spurs broad and spatula like.

Males: Males externally similar to females. Antennal club 2½ times the length of first antennal segment. Hind tibial spurs spine like and pointed.

Male genitalia: Spiculum gastrale with two slightly sclerotised areas, one on each side, some times connected, between the two arms. Dorsal apophyses as long as the width of the stem at the base.

3.6 EVALUATION OF BIO AGENTS AND PLANT PRODUCT AGAINST ROOT GRUBS, *L. lepidophora* IN ARECANUT

Evaluation of bioagents was carried out against arecanut root grubs both in laboratory and field conditions. Bioagents include two species of entomopathogenic fungi namely, *M. anisopliae* and *B. brongniartii*. These were evaluated at concentration level of 2×10^8 conidia per gram with dose of 10 and 20 grams per palm. Plant products, namely strychnine tree (*Strychnos nux vomica*: Loganiaceae) (it is called 'Kasaraka' in Kannada) and a mixture of soap nut (*Sapindus emarginatus*: Sapindaceae) and neem oil (*Azadirachta indica*) these were evaluated at 5 and 10 per cent concentration as aqueous solutions. These bioagents and

Table 1: Treatment details in evaluation of bio agents against root grub, *L. lepidophora* in arecanut

Sl. No.	Treatments	Dose
T1	<i>Metarrhizium anisopliae</i> 2x10 ⁸ conidia /g + vermicompost	20 gram fungus + 2 kg vermicompost per palm
T2	<i>Metarrhizium anisopliae</i> 2x10 ⁸ conidia /g + vermicompost	10 gram fungus + 2 kg vermicompost per palm
T3	<i>Beauveria brongniartii</i> 2x10 ⁸ conidia /g + vermicompost	20 gram fungus + 2 kg vermicompost per palm
T4	<i>Beauveria brongniartii</i> 2x10 ⁸ conidia /g + vermicompost	10 gram fungus + 2 kg vermicompost per palm
T5	Mixture of soap nut (<i>Sapindus emarginatus</i>) aqueous extract and neem oil aqueous extract	5 %solution (3 litre per palm)
T6	Mixture of soap nut (<i>Sapindus emarginatus</i>) aqueous extract and neem oil aqueous extract	10 %solution (3 litre per palm)
T7	Strychnine (<i>Strychnos nux vomica</i>) seed extract	5 %solution (3 litre per palm)
T8	Strychnine (<i>Strychnos nux vomica</i>) seed extract	10 %solution (3 litre per palm)
T9	Chlorpyriphos 20EC	3 ml per tree (two litre solution per palm)
T10	Phorate 10G	25 gram per palm
T11	Control	

plant products were compared with two synthetic insecticides; Chlorpyriphos 20EC and Phorate 10G granules. All these treatment compared again with untreated control (Table 1).

3.6.1 Evaluation of bio agents and plant products against arecanut root grubs, *L. lepidophora* in laboratory condition.

In this evaluation, the entomopathogenic fungi and plant products as listed in table 1 were applied on arecanut root grubs in a captivity condition. For this, late instar larvae of *L. lepidophora*, were collected from the infested arecanut garden by digging. They were released into autoclaved soil medium in rectangular plastic trays of size 30X 24X 4 cm. Required moisture level was maintained by adding water to the soil. Potato tubers were placed in each box for the feeding of grubs. For each treatment 27 larvae were released and replicated three times. Trial was conducted at room temperature of 25 ±1°C. All the boxes were secured with a lid on them. All the treatments as listed in Table 1 were applied on root grubs with a dosage mentioned against them. A separate untreated control was also maintained without any treatment. Application of two fungal pathogens was done by mixing their powder formulation in the soil before release of larvae. Aqueous solutions of plant products and chlorpyriphos 20 EC were drenched into soil and mixed thoroughly.

Observations on larval mortality were recorded at 7, 14, 30, 45 and 60 days after treatment imposition and per cent larval mortality was calculated by the formula;

$$\text{Per cent mortality} = \frac{\text{Number of dead larvae}}{\text{Total number of larvae}} \times 100$$

3.6.2 Evaluation of bio agents and plant product against root grubs, *L. lepidophora* in field condition

Field trial for evaluation of bioagents and plant products was carried out in arecanut garden at Mavinakoppa village near Sirsi. Trial was laid out in Randomised Block Design in already infested garden. All eleven treatments (Table 1) were replicated three times and completely randomised. In each treatment three arecanut trees were taken and labelled on tree trunks with paint. The trees for the trial were of eighteen years old. Each tree was observed for the larval population in the root zone and it was regulated to ten grubs per palm either by releasing or removing the grubs artificially.

Individual treatments were applied in the following ways. Fungal pathogen treatments were applied at root zone of arecanut palm along with the vermicompost according to the dosage mentioned in Table 1. *M. anisopliae* was procured from Department of Agricultural entomology, College of Agriculture, University of Agricultural Sciences, Dharwad. Another fungal pathogen *B. brongniartii* was procured from a private firm, Pest Control of India, Bangalore.

Both plant product extracts were prepared fresh before application of treatments. Aqueous extract of Strychnine seeds was prepared in two concentrations of five and ten per cent. Required quantity of Strychnine seeds were ground into coarse powder and the powder was tied in a thin cotton cloth and immersed in water for twelve hours at room temperature. Solution was filtered and applied to the root zone of arecanut by drenching the soil around the tree trunk.

Aqueous extract of soap nut was first prepared separately by soaking the dry soap nut fruits in water for seventy two hours. Later, the soaked fruits were squeezed thoroughly to get profuse frothing. The solution was filtered and readily available neem oil was mixed and stirred well. Two concentrations of five and ten per cent solutions were prepared. To prepare five percent solution, 500 g of dry fruits were soaked in 2.5 litres of water and mixed with 500 ml of neem oil and volume made up to 10 litres. Ready solution was applied to the soil in root zone of arecanut tree by drenching around the tree trunk.

In case of Chlorpyrifos 20EC, 3 ml of insecticide formulation in one litre of water was prepared and such two litres of solution was drenched to the soil around the tree.

Phorate 10G granules were applied @ of 25g per palm by broadcasting at the base of the tree.

Observation on larval mortality was recorded by digging the soil at the base of tree and counting the grubs. Observations were recorded on 7, 14, 30, 45 and 60 days after treatment imposition.

Data on per cent mortality in both laboratory and field trial was subjected to Arcsine transformation. The treatment means were compared by using Duncan's Multiple Range Test (DMRT).

4. RESULTS

Results of different studies on arecanut root grub are presented in following paragraphs. The results include information collected from survey of root grub infested arecanut gardens during 2006-07 in Uttara Kannada and Shimoga districts along with their species identification, yield loss due to root grubs, and root grub management studies with bioagents and plant products.

4.1 SURVEY FOR ROOT GRUB INFESTED ARECANUT GARDEN IN UTTARA KANNADA AND SHIMOGA DISTRICTS

4.1.1 Population density of different stages of arecanut root grub in different taluks

Sirsi taluk

In the first round of survey during August 2006, in Sirsi taluk (Table 3 to 6) egg populations recorded was 0.4 eggs per palm. Further, in survey during October, 2006, January and March, 2007 there were no eggs recorded. First instar larval count recorded in Sirsi taluk was 0.08, 0.04, 0.00 and 0.00 larvae per palm during August, October, January and March survey, respectively. Second instar grubs were present in the field from August (2006) to January (2007) ranging from 0.04 to 0.36 grub per palm. Third instar grubs were recorded in all four rounds of survey (August, 2006-March, 2007) ranging from 0.32 to 4.20 grubs/palm. In the taluk, highest grubs were noticed in Korlakatta (27 grubs/palm) and Devanahalli village (32 grubs/palm) and with an average of 7.2 and 8.4 grubs per palm respectively in these gardens. Pupal and adult, stages were noticed in August with an average of 0.04 per palm respectively.

Yellapura taluk

During survey, no eggs and first instar grubs were noticed in Yellapura taluk. Second instar root grubs were found from August to October 2006, in which maximum of 0.28 grubs per palm noticed during August. The lowest number 0.08 grubs per palm were recorded in October, 2006. Third instar grubs, recorded in all rounds of survey (August, 2006 to January, 2007) was ranging from 0.00 to maximum of 0.28 per palm. No adults and pupae were recorded in Yellapura taluk during all the rounds of survey.

Siddapura taluk

Survey conducted in Siddapura taluk revealed that, eggs were observed in the month of August, 2006 at a rate of 1.04 eggs/palm. No first instar grubs were noticed in the taluk during survey. In case of second and third instars, both were observed from August to October, 2006 with a range of 0.64 to 1 and 0.24 to 0.6 grubs/palm, respectively. No pupae were noticed in any of the gardens. A typical adult emergence was noticed in large number in one garden of village Yalugaar, in Siddapura taluk with 34 beetles captured. Peak emergence of beetle was observed from 6:45 PM to 7:45 PM and later mating of adults took place on areca foliage at height of about 3 to 4 m (Plate 1).

Sagara taluk

In Sagara taluk, no eggs or first instar grubs were recorded during the survey in August, October 2006 and January, March 2007. Second instar grubs were observed from August to October 2006 with a range of 0.08 to 0.24 grubs per palm. Third instar grubs were recorded from August 2006 to January 2007 with maximum 1.64 grubs per palm during August 2006 and as lowest 0.24 grub/palm in the month of January 2007. During the fourth round of survey (March, 2007), none of root grub stages were recorded. In this taluk no pupae and adults were recorded during all the four rounds of survey.

Thirthahalli taluk

Eggs of *Leucopholis lepidophora* were observed in the month of August at the rate of 0.16 per palm. First instar grubs were noticed from August 2006 to October 2006 with a range of 0.04 to 0.12 per palm. Second instar grubs were found at the rate of 0.56, 0.48 and 0.16 per palm in the months of August, October and January respectively. Third instar grubs were



Eggs



Instar



II Instar



III Instar



Pupa



Adult

Plate 3. Photographs showing different life stages of arecanut root grub *L. lepidophora*

observed in all four rounds of survey with maximum of 4.56 per palm in August 2006 and minimum of 0.08 per palm in March 2007. Highest number of grubs was recorded in Hasigae and Tenkbylu villages at the rate of 28 to 31 grubs per palm. During the survey only one adult recovered during August 2006.

4.1.2 Depth of larval availability in soil of arecanut ecosystem

Sirsi taluk

In all the four rounds of survey in Sirsi taluk, the depth of larval availability in root zone recorded was 18.6 cm (August, 2006), 20.6 cm (October, 2006), 39.0 cm (January, 2007) and 60.0 cm (March, 2007) (Table 2, 3, 4 and 5).

Yellapura taluk

Depth of larval availability near root zone in Yellapura taluk was 19.4 cm, 21.4 cm, 39.4 cm and 60.0 cm during August (2006), October (2006), January (2007) and March (2007), respectively (Table 2, 3, 4 and 5).

Siddapura taluk

In Siddapura taluk, arecanut root grubs were encountered near root zone with a depth of 18.2 cm, 20.2 cm, 38.2 and 60 cm during August (2006), October (2006), January (2007) and March (2007), respectively (Table 2, 3, 4 and 5).

Sagara taluk

In all the four rounds of survey in Sagara taluk, the depth of root grub availability in root zone recorded was 18.6 cm (August, 2006), 20.6 cm (October, 2006), 38.6 cm (January, 2007) and 60.0 cm (March, 2007) (Table 2, 3, 4 and 5).

Thirthahalli taluk

Depth of root grub availability near root zone in Thirthahalli taluk during four rounds of survey was as follows, 19.8 (August, 2006), 21.8 (October, 2006), 39.8 (January, 2007) and 60 cm (March, 2007) (Table 2, 3, 4 and 5).

4.1.3 Studies on species identification of arecanut root grub

Root grub samples collected during survey from all five taluks were sent to taxonomic identification. It was confirmed that *Leucopholis lepidophora* Blanch is the species found damaging arecanut in these five taluks.

4.1.4 Influence of rainfall on root grub population

Relationship between rainfall and grub population was worked out by using regression. Regression formula obtained for different taluk was as follows, Sirsi $Y = -0.0001X^2 + 0.0845x + 0.98$, ($R^2=0.9162$), Siddapura $Y = -6E-06X^2 + 0.0065X + 0.66$ ($R^2=0.7204$), Yellapura $Y = -9E-06X^2 + 0.0063 + 0.06$ ($R^2=0.9591$), Sagara $Y = -4E-05X^2 + 0.025X + 0.12$ ($R^2 = 0.9872$) and Thirthahalli $Y = 0.0001X^2 + 0.1112X + 0.16$ ($R^2=0.9994$) (Table 6).

4.1.5 Types of garden and root grub population

During the survey of root grub infested arecanut gardens, two types of gardens were recorded. First type: old and traditional gardens and second type: new gardens with paddy fields converted into arecanut gardens. Surveyed gardens constituted 74.10, 82.60, 97.60, 89.70 and 94.45 per cent of new and paddy fields converted into areca gardens in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli taluks respectively and remaining area was in old traditional types of gardens (Plate 1).

The root grub population in new and paddy field converted gardens was ranging from 0.42 to 5.1 grubs per palm. Grub population in different taluks in new gardens was 5.1, 0.42, 0.42, 1.52 and 4.82 grubs per palm in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli, respectively.

The area under cultivation in old traditional gardens during the survey was 25.90, 17.40, 2.40, 10.30 and 5.55 per cent, respectively in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli taluks. The total grub counts recorded per palm in these old gardens was 1.10,

Table 2: Population density of different stages of arecanut root grub, *L. lepidophora* in different taluks during August 2006

Taluks and villages	Mean no. of different stages of <i>L. lepidophora</i> per palm							Mean soil depth (cm)	Mean rainfall (mm)
	Eggs	I instar	II instar	III instar	Total grubs	Pupa	Adult		
Sirsi									
Mavinakoppa	-	-	0.2	4.2	4.4	0.2	0.2	18	632.8
Dodnalli	-	-	1.0	0.8	1.8	-	-	20	
Korlakatta	-	-	0.2	8.4	8.6	-	-	20	
Sirsimakki	-	0.4	0.4	0.4	1.2	-	-	15	
Devanahalli	2	-	-	7.2	7.2	-	-	20	
Mean	0.4	0.08	0.36	4.20	4.64	0.04	0.04	18.6	
Yellapura									
Bisgodu	-	-	-	-	-	-	-	20	870.7
Kavadikere	-	-	0.8	1	1.8	-	-	22	
Magodu	-	-	0.6	-	0.6	-	-	15	
Umachgi	-	-	-	0.4	0.4	-	-	20	
Kolikere	-	-	-	-	-	-	-	20	
Mean	-	-	0.28	0.28	0.56	-	-	19.4	
Siddapura									
Halageri	-	-	0.6	-	0.6	-	-	22	891.6
Menasi	-	-	-	0.6	0.6	-	-	15	
Yalugaar	3.4	-	-	0.6	0.6	-	6.8	20	
Dodmane	1.8	-	4.4	1.0	5.4	-	-	16	
Kodigadde	-	-	-	0.8	0.8	-	-	18	
Mean	1.04	-	1.0	0.6	1.6	-	0.96	18.2	
Sagara									
B.R.Keppigol	-	-	-	2.2	2.2	-	-	18	562.9
Kaspadi	-	-	1.2	2.0	3.2	-	-	15	
Honagodu	-	-	-	-	-	-	-	20	
Sirivanthae	-	-	-	1.4	1.4	-	-	20	
Heggodu	-	-	-	2.6	2.6	-	-	20	
Mean	-	-	0.2	1.64	1.88	-	-	18.6	
Thirthahalli									
Hasigae	0.8	-	-	7.6	7.6	-	0.2	20	1056.8
Tenkbylu	-	0.6	1.2	5.8	7.6	-	-	19	
Bharthipura	-	-	1.0	2.4	3.4	-	-	22	
Demplapura	-	-	1.4	3.2	4.6	-	-	20	
Ranjada katte	-	-	-	3.8	3.8	-	-	18	
Mean	0.16	0.12	0.56	4.56	5.40	-	0.04	19.8	

Table 3: Population density of different stages of arecanut root grub, *L. lepidophora* in different taluks during October, 2006

Taluks and villages	Mean no. of different stages of <i>L. lepidophora</i> per palm							Mean soil depth(cm)	Mean rainfall (mm)
	Eggs	I instar	II instar	III instar	Total grubs	Pupa	Adult		
Sirsi									
Mavinakoppa	-	-	0.4	3.80	4.20	-	-	20	36.8
Dodnalli	-	-	-	1.20	1.20	-	-	22	
Korlakatta	-	-	-	7.40	7.40	-	-	22	
Sirsimakki	-	0.2	0.6	0.20	1.00	-	-	17	
Devanahalli	-	-	-	5.80	5.80	-	-	22	
Mean	-	0.04	0.20	3.68	3.92	-	-	20.6	
Yellapura									
Bisgodu	-	-	-	-	-	-	-	22	37.8
Kavadikere	-	-	0.2	0.8	1.0	-	-	24	
Magodu	-	-	0.2	0.2	0.4	-	-	17	
Umachgi	-	-	-	-	-	-	-	22	
Kolikere	-	-	-	-	-	-	-	22	
Mean	-	-	0.08	0.20	0.28	-	-	21.4	
Siddapura									
Halageri	-	-	-	-	-	-	-	24	35.0
Menasi	-	-	-	0.2	0.2	-	-	17	
Yalugaar	-	-	-	0.4	0.4	-	-	22	
Dodmane	-	-	3.2	0.4	3.6	-	-	18	
Kodigadde	-	-	-	0.2	0.2	-	-	20	
Mean	-	-	0.64	0.24	0.88	-	-	20.2	
Sagara									
B.R.Keppigol	-	-	-	1.60	1.60	-	-	20	43.9
Kaspadi	-	-	0.4	1.20	0.60	-	-	17	
Honagodu	-	-	-	0.4	0.40	-	-	22	
Sirivanthae	-	-	-	0.8	0.80	-	-	22	
Heggodu	-	-	-	1.4	1.40	-	-	22	
Mean	-	-	0.08	1.08	0.96	-	-	20.6	
Thirthahalli									
Hasigae	-	-	-	7.00	7.00	-	-	22	38.6
Tenkbylu	-	0.2	0.80	4.60	5.60	-	-	21	
Bharthipura	-	-	0.60	2.20	2.80	-	-	24	
Demplapura	-	-	1.00	2.60	3.60	-	-	22	
Ranjada katte	-	-	-	2.20	2.20	-	-	20	
Mean	-	0.04	0.48	3.72	4.24	-	-	21.8	

Table 4: Population density of different stages of arecanut root grub, *L. lepidophora* in different taluks during January 2007

Taluks and villages	Mean no. of different stages of <i>L. lepidophora</i> per palm							Mean soil depth(cm)	Mean rainfall (mm)
	Eggs	I instar	II instar	III instar	Total grubs	Pupa	Adult		
Sirsi									
Mavinakoppa	-	-	0.2	0.60	0.80	-	-	38	0.00
ARS (pepper)*	-	-	-	0.80	0.80	-	-	39	
Korlakatta	-	-	-	4.40	4.0	-	-	39	
Hutgar	-	-	-	1.00	1.00	-	-	39	
Devanahalli	-	-	-	1.20	1.20	-	-	40	
Mean	-	-	0.04	1.60	1.64	-	-	39	
Yellapura									
Machikere	-	-	-	0.60	0.60	-	-	40	0.00
Kavadikere	-	-	-	-	-	-	-	42	
Magodu	-	-	-	-	-	-	-	35	
Umachgi	-	-	-	-	-	-	-	40	
Kolikere	-	-	-	-	-	-	-	40	
Mean	-	-	-	0.12	0.12	-	-	39.4	
Siddapura									
Kodsara	-	-	-	-	-	-	-	42	0.00
Menasi	-	-	-	-	-	-	-	35	
Kansuru	-	-	-	-	-	-	-	40	
Dodmane	-	-	-	-	-	-	-	36	
Kodigadde	-	-	-	-	-	-	-	38	
Mean	-	-	-	-	-	-	-	38.2	
Sagara									
B.R.Keppigol	-	-	-	-	-	-	-	38	0.00
Kaspadi	-	-	-	-	-	-	-	35	
Honagodu	-	-	-	-	-	-	-	40	
Srivanthae	-	-	-	0.8	0.8	-	-	40	
Heggodu	-	-	-	0.4	0.4	-	-	40	
Mean	-	-	-	0.24	0.24	-	-	38.6	
Thirthahalli									
Hasigae	-	-	-	0.4	0.4	-	-	40	0.00
Tenkbylu	-	-	-	-	-	-	-	39	
Bharthipura	-	-	-	0.2	0.2	-	-	42	
Demplapura	-	-	0.4	0.2	0.6	-	-	40	
Ranjada katte	-	-	-	-	-	-	-	38	
Mean	-	-	0.08	0.16	0.24	-	-	39.8	

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Table 5: Population density of different stages of arecanut root grub, *L. lepidophora* in different taluks during March 2007

Taluks and villages	Mean no. of different stages of <i>L. lepidophora</i> per palm							Mean soil depth(cm)	Mean rainfall (mm)
	Eggs	I instar	II instar	III instar	Total grubs	Pupa	Adult		
Sirsi									
Mavinakoppa	-	-	-	-	-	-	-	60	0.00
ARS (pepper)	-	-	-	-	-	-	-	60	
Korlakatta	-	-	-	1.6	1.6	-	-	60	
Hutgar	-	-	-	-	-	-	-	60	
Devanahalli	-	-	-	-	-	-	-	60	
Mean	-	-	-	0.32	0.32	-	-	60	
Yellapura									
Machikere	-	-	-	-	-	-	-	60	0.00
Kavadikere	-	-	-	-	-	-	-	60	
Magodu	-	-	-	-	-	-	-	60	
Umachgi	-	-	-	-	-	-	-	60	
Kolikere	-	-	-	-	-	-	-	60	
Mean	-	-	-	-	-	-	-	60	
Siddapura									
Kodsara	-	-	-	-	-	-	-	60	0.00
Menasi	-	-	-	-	-	-	-	60	
Kansuru	-	-	-	-	-	-	-	60	
Dodmane	-	-	-	-	-	-	-	60	
Kodigadde	-	-	-	-	-	-	-	60	
Mean	-	-	-	-	-	-	-	60	
Sagara									
B.R.Keppigol	-	-	-	-	-	-	-	60	0.00
Kaspadi	-	-	-	-	-	-	-	60	
Honagodu	-	-	-	-	-	-	-	60	
Sirivanthae	-	-	-	-	-	-	-	60	
Heggodu	-	-	-	-	-	-	-	60	
Mean	-	-	-	-	-	-	-	60	
Thirthahalli									
Hasigae	-	-	-	-	-	-	-	60	0.00
Tenkbylu	-	-	-	-	-	-	-	60	
Bharthipura	-	-	-	-	-	-	-	60	
Demplapura	-	-	-	-	-	-	-	60	
Ranjada katte	-	-	-	0.4	0.4	-	-	60	
Mean	-	-	-	0.08	0.08	-	-	60	



Plate 5. Different positions of arecanut root grub in the soil at the base of the arecanut palm

0.00, 0.45, 0.00 and 0.00 in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli taluks, respectively (Table 7).

4.1.6 Damage symptoms

Damage symptoms observed during the survey in five taluks reveal that the late instar larvae were found to feed on the terminal tender portion of the roots. The remaining roots in bole region were also eaten. Later, grub move towards the core of bole region and start feeding by tunnelling to little extent.

Severely infested trees with root grubs exhibited yellowing, pencilling, shortening of internodes length, root damage, reduced crown width, reduced nut yield and toppling of trees (Plate 2) (Table 8).

In Sirsi taluk, 80 per cent of visited new and paddy field converted into arecanut garden showed root damage, yellowing observed in 60 per cent garden. Only 20 per cent garden showed pencilling. Toppling was a common phenomenon in 40 per cent of surveyed garden. In contrary, 22 per cent arecanut garden showed root damage and 20 per cent garden showed yellowing, apart from that no other symptoms were observed in old and traditional arecanut belts due to root grub attack.

Table 6: Rain fall and root grub population

Sl. No.	Taluks	Regression formula	Regression coefficient (R ²)
1	Sirsi	$Y = -0.0001X^2 + 0.0845x + 0.98$	0.9162
2	Siddapura	$Y = -6E-06X^2 + 0.0065X + 0.66$	0.7204
3	Yellapura	$Y = -9E-06X^2 + 0.0063X + 0.06$	0.9591
4	Sagara	$Y = -4E-05X^2 + 0.025X + 0.12$	0.9872
5	Thirthahalli	$Y = 0.0001X^2 + 0.1112X + 0.16$	0.9994

In Yellapura taluk, root damage was observed in 75 per cent area, whereas yellowing and pencilling in 62.5 per cent area, respectively. Toppling was more evident in 18 per cent area visited under new and paddy field converted as arecanut garden. But its counterpart i.e. traditional arecanut garden had not showed any damage symptoms.

Area surveyed under new and paddy field converted arecanut garden in Siddapura taluk showed 60, 40 and 19 per cent of root damage, yellowing and pencilling, respectively. Among the surveyed garden no garden showed toppling. In contrary, in case of old and traditional arecanut garden, root damage was observed in 77 per cent area, 32 per cent visited garden showed yellowing, pencilling and toppling were evident in 5 and 3 per cent surveyed garden, respectively.

Condition of area visited under new and paddy field converted into arecanut garden in Sagara and Thirthahalli was as follows. In both the taluk root damage were evident (80% visited garden in Sagara and almost all garden in Thirthahalli), yellowing observed in 85.3 per cent gardens of Sagara, whereas 83.3 per cent garden in Thirthahalli. Pencilling and toppling were more common in Thirthahalli (pencilling in 80 per cent and toppling in 43.3 per cent visited area), but in Sagara both pencilling and yellowing were least (pencilling in 50 per cent and toppling in 14.2 per cent visited area) compared to Thirthahalli. Similarly no visual symptoms were observed in old and traditional arecanut belts, in both the taluks.

4.1.7 Adoption of different management practices by farmers in Uttara Kannada and Shimoga districts

During the survey, the farmers were interviewed for the management practices adopted by them against arecanut root grub. Based on use of different management practices adopted by the farmers they can be grouped into 5 categories. They are: (1) Chemical control with insecticides (2) Use of botanical insecticides (3) Use of bioagents (4) Mechanical control (5) Other method like use of salt. There was also another category of farmers who did not use any control measures in their garden against arecanut root grub. The data collected on different methods adopted by farmers (Table 9) shows that 64.50 per cent farmers were found

Table 7: Area and larval density of arecanut root grub, *L. lepidophora* in traditional and new gardens

Taluks	Total area visited (ha)	Area of garden		Larval population (grub count/palm)	
		New and paddy fields converted into arecanut gardens (%)	Old and traditional arecanut gardens (%)	New and paddy field converted into arecanut garden	Old and traditional arecanut gardens
Sirsi	10.80	74.10	25.90	5.10	1.10
Yellapura	09.20	82.60	17.40	0.42	0.00
Siddapura	07.58	97.60	2.40	0.42	4.50
Sagara	03.92	89.70	10.30	4.52	0.00
Thirthahalli	07.20	94.45	5.55	4.82	0.00



Healthy arecanut root



Damaged arecanut root by root grub



Yellowing

Plate 2. Different damage symptoms of arecanut root grub *L. lepidophora*



Healthy arecanut garden



Reduced internodal length



Penciling



Toppling

Plate 2. (Contd.....) Visuals damage symptoms in arecanut due to root grub infestation

Table 8: Extent of damage symptoms in new and paddy field converted into arecanut gardens and in old and traditional gardens

Taluk	Root damage		Yellowing		Pencilling		Toppling	
	New and paddy fields converted into arecanut garden (%)	Old and traditional arecanut garden (%)	New and paddy fields converted into arecanut garden (%)	Old and traditional arecanut garden (%)	New and paddy fields converted into arecanut garden (%)	Old and traditional arecanut garden (%)	New and paddy fields converted into arecanut garden (%)	Old and traditional arecanut garden (%)
Sirsi	80	22	60.0	20	20	0	40.0	0
Yellapura	75	0	62.5	0	62.5	0	18.0	0
Siddapura	60	77	40.0	32	19	5	0.0	3
Sagara	80	0	85.3	0	43.3	0	14.2	0
Thirthahalli	100	0	83.3	0	80.0	0	50.0	0

Table 9: Adoption of different management practices by farmers in Uttara Kannada and Shimoga districts

Sl. No.	Management practice	% Farmers using this method
1	Application of insecticides (either chlorpyriphos or phorate)	64.50
2	Application of botanical insecticides(Neem and soap nut)	22.57
3	Use of bioagents (Entomopathogenic fungi)	6.45
4	Mechanical control (Digging and hand collection)	9.67
5	Application of salt	6.42
6	No control measures	9.20

to have used chemical control by using insecticides to tackle the root grub problem. Among the insecticides, usage of chlorpyriphos 20 EC was wide spread with a varied dosage of 3 ml/palm to 12 ml/palm followed by phorate 10G granules with a varied dose of 20 to 50 g per tree.

Use of botanical insecticides was accounted for 22.57 per cent of farmers. These farmers used neem (*Azadirachta indica*), Strychnine (*Strychnos nux vomica*) and soap nut (*Sapindus emarginatus*) as botanical insecticide plants. Use of neem product accounted for 12.9 per cent farmers in which they used neem cake with dose of 0.5 kg to 2 kg per palm and also neem oil. Use of Strychnine and soap nut together accounted for 9.67 per cent farmers who used a concentration of 5 to 10 per cent aqueous solution.

Mechanical collection of root grubs in the garden recorded 9.67 per cent farmers, who usually practiced this method in the months of July and August. During the survey, an instance of collection of 18 kg of root grubs in a week time was noticed in a village near Thirthahalli in July 2006.

Only 6.45 per cent of farmers were found using entomopathogenic fungi in root grub management. This was observed only in Sirsi taluk. Among the fungi *M. anisopliae* was most common one.

Other methods used by farmers included the use of salt at the rate of 50 kg to 100 kg per acre to manage the root-grub menace which accounted for 6.42 per cent farmers. 9.20 per cent interviewed farmers did not take up any control measures against root grubs in their garden.

4.1.8 Natural enemies of arecanut root grub, *L. lepidophora* recorded in Uttara Kannada and Shimoga districts during the survey in August 2006 to March 2007

A number of natural enemies including parasites, predators and pathogens on arecanut root grubs were recorded during field visits (Table 10) (Plate 4).

Predators

False vampire bat

A species of false vampire bat was found roasting in attics of pump houses near to arecanut garden at Dodnalli and Hasigae. It was observed that floors of both the pump houses littered with elytra of root grubs including *Leucopholis lepidophora*.

Wild boar

The Indian wild boar, *Sus cristatus* (Wagner), was found to be major predator *Leucopholis lepidophora* particular in larval stages. A clear evidence of wild boar predation on third instar larvae was observed in Tenkbylu (Thirthahalli taluk). Extensive soil disturbance around the root grub infested palm was more common in that plot. On checking, the absence of white grubs in the wild boar disturbed area was evident than in the adjacent undisturbed area.

Garden lizard

An unknown species of garden lizard was found to be eating on grubs during second round survey in Dodmane (Siddapura). Lizard picked up grubs only during excavation around the palm, then climbed up on tree and swallowed whole grub as such. Same thing noticed five times in that garden.

Parasite

Scoliidae: Silken pupae of scoliid was encountered during final round of survey (March, 2007) in Korlakatta (Sirsi taluk). The silken pupa of scoliid was invariably found associated with the carcass of III instar larvae of *L. lepidoptera*. Live larva of the scoliid or adult or freshly parasitized larva of *L. lepidophora* were not noticed during the course of study.

Entomopathogen

Beauveria sp.

A mycosed III instar larvae was found in Korlakatta during March, 2007. it was confirmed after microscopic study as *Beauveria* sp. Further studies on the species identification are being continued at AICRP on white grubs, GKVK, Bangalore.

4.2 ESTIMATION OF YIELD LOSS IN ARECANUT DUE TO ROOT GRUB INFESTATION

In studies on yield loss due to arecanut root grub, it was found that higher nut yield of 8.85 kg per palm was recorded in protected plot as against 7.05 kg in unprotected plot (Table 11). The calculated 't' value for this study was 1.60 and showed non-significant yield levels in both protected and unprotected plots.

The grub population in protected plot was 2.2 grubs per palm during one day before treatment with insecticides and the grub population was 0.0, 0.1, 0.0 and 0.1 grubs per palm at 30, 60, 90 and 120 days after treatment, respectively.

In unprotected plot grub population before treatment was 2.1 grubs per palm and the grub population was 2.1, 2.1, 2.0 and 2.0 grubs per palm at 30, 60, 90 and 120 days after treatment.

Table 10: Natural enemies of arecanut root grub, *L. lepidophora* recorded in Uttara Kannada and Shimoga districts during the survey in August 2006 to March 2007

Natural enemy	Stage of insect	Remarks
Predators		
False vampire bat <i>Megaderma spasm</i> (Linnaeus)	Adult	Field observations
Wild boar <i>Sus cristatus</i> (Wagner)	All stages of grubs	Field observations
Garden lizard (unknown species)	All stages of grubs	Field observations
Parasite		
Hymenoptera: Scoliidae	III instar grubs	Field observations
Pathogen		
<i>Beauveria</i> sp.	III instar grubs	Field observations

4.3 EVALUATION OF BIOAGENTS AND PLANT PRODUCTS AGAINST ARECANUT ROOT GRUB, *L. lepidophora* UNDER LABORATORY CONDITION AND FIELD CONDITION

4.3.1 Evaluation of bioagents and plant products against arecanut root grub, *L. lepidophora* under laboratory condition

Results obtained in the laboratory evaluation of bioagents and plant products against arecanut root grub are elucidated below.

Seven days after treatment

The mortality of root grubs after seven days of treatment ranged from 0.00 to 62.96 per cent among all the treatments, the highest mortality of 62.96 per cent was recorded in treatment with chlorpyrifos 1.2 per cent (Table 12). Chlorpyrifos 1.2 per cent was



False vampire bat roosting in pump house sealing



Extensive soil disturbance around arecanut palm for root grubs by the wild boar



Garden lizard with arecanut root grub



Dead arecanut root grub with fungal mycelia *Beauveria* sp.



A hymenopteran parasitic wasp cocoon found on arecanut root grub

Plate 4. Natural enemies of arecanut root grub (*L. lepidophora*) recorded during the survey in Uttara Kannada and Shimoga districts

Table 11: Studies on yield loss due to arecanut root grub

Treatments	Mean number of grubs/palm					Average nut yield (in kgs) at the end of season (per palm)
	1 DBT	30 DAT	60 DAT	90 DAT	120 DAT	
Protected	2.2	-	0.1	0.0	0.1	8.85
Unprotected	2.1	2.1	2.1	2.0	2.0	7.05
Table 't' value						2.100
Calculated 't' value						1.60
P						0.12

significantly superior over all other treatments. This was followed by phorate 2.5 per cent with 51.84 per cent mortality.

Among the plant extracts, Strychnine seed extract 10 per cent aqueous solution recorded 33.33 per cent larval mortality, which was significantly differed over its lower concentration of 5 per cent aqueous solution (22.22%). Another plant product, aqueous mixture of soap nut + neem oil concentration 5 per cent recorded 40.74 per cent and same mixture at 10 per cent concentration recorded 44.44 per cent larval mortality. Ten per cent solution recorded significantly higher larval mortality over 5 per cent.

Among two fungal pathogens, *M. anisopliae* with 2×10^8 and 4×10^8 conidial doses recorded no mortality of root grubs at 7 days after treatment. *B. brongniartii* with 2×10^8 and 4×10^8 conidial doses also recorded no mortality of root grubs at 7 days after treatment.

Fourteen days after treatment

After 14 days of treatment, the mortality of root grubs, among all the treatments ranged from 0.00 to maximum of 74.07 per cent. The highest per cent mortality was recorded in treatment with Chlorpyrifos dose 1.2 per cent. This treatment was significantly superior over all other treatments. Phorate 2.5 per cent recorded larval mortality of 55.55 per cent.

Among the plant products, aqueous mixture of soap nut and neem oil at 5 and 10 per cent concentrations recorded 44.44 and 55.55 per cent larval mortality, respectively. Ten per cent mixture was significantly superior over 5 per cent mixture and on par with phorate 2.5 per cent.

Strychnine seed extract at 5 and 10 per cent recorded 33.33 and 40.74 per cent larvae mortality, respectively and statistically differed with each other.

Among the fungal pathogens, *M. anisopliae* with 2×10^8 and 4×10^8 conidial doses recorded no mortality of root grubs at 14 days after treatment. *B. brongniartii* with 2×10^8 and 4×10^8 conidial doses also recorded no mortality of root grubs at 14 days after treatment.



Strychnine (*Strychnos nux vomica*) tree



Strychnine seeds



Neem seeds



Neem (*Azadirachta indica*) tree



Soap nut (*Sapindus emarginatus*) tree



Soapnut dried fruits



Plate 7. *Metarrhizium* infested arecanut root grub

Thirty days after treatment

At 30 days of treatment the larval mortality was ranging from 0.00 to highest of 88.89 per cent. The highest mortality was brought by treatment of chlorpyrifos 1.2 per cent. This treatment stood significantly superior over all other treatments and next best treatment was phorate 2.5 per cent which recorded 70.37 per cent larval mortality (Table 12).

In plant extracts, aqueous mixture of soap nut and neem oil at 10 per cent concentration showed higher per cent mortality (66.67%) and significantly superior over its lower dose of 5 per cent which recorded 55.55 per cent larval mortality. Aqueous extract of Strychnine at 5 and 10 per cent concentrations recorded 44.44 and 59.25 per cent larval mortality respectively.

Among the mycopathogens, *M. anisopliae* with 4×10^8 conidia found superior (18.52%) over its lower dose of 2×10^8 conidia (11.11%). Another fungal pathogen *B. brongniartii* with 4×10^8 conidia found superior (14.81%) over its lower dose of 2×10^8 conidia (11.11%) in bringing larval death.

Forty five days after treatment

At 45 days of treatment, the mean per cent grub mortality was ranging from zero to maximum of 88.89 per cent. Highest mortality was scored by treatment of chlorpyrifos 1.2 per cent (88.89%). This treatment rose significantly superior over all treatments and next best treatment was phorate 2.5 per cent which recorded 74.07 per cent root grub mortality (Table 12).

Among plant extracts, aqueous mixture of soap nut and neem oil at 5 and 10 per cent concentrations recorded 59.26 and 70.37 per cent mortality respectively. Ten per cent mixture was significantly superior over 5 per cent mixture and found at par with phorate 2.5 per cent.

Strychnine seed extract at 5 and 10 per cent aqueous solutions recorded 48.14 and 62.96 per cent larval mortality, respectively and statistically differed with each other.

Among the mycopathogens, *M. anisopliae* with 4×10^8 conidia showed 22.22 per cent mortality and found superior over its lower dosage of 2×10^8 conidia with 11.11 per cent larval mortality. *Beauveria brongniartii* with 4×10^8 treatments with 2×10^8 and 4×10^8 conidia recorded 11.11 and 18.52 per cent grub mortality, respectively. *B. brongniartii* with 4×10^8 conidia was found significantly superior over its lower dose of 2×10^8 conidia and comparable with *M. anisopliae* with 4×10^8 conidia.

Sixty days after treatment

At 60 days after treatment the larval mortality was ranging from zero to maximum of 88.89 per cent. Chlorpyrifos 1.2 per cent recorded highest per cent mortality of root grub (88.89%). Next best treatment was Phorate 2.5 per cent which recorded 77.77 per cent larval mortality.

In case of plant extracts, soap nut and neem oil aqueous mixture at 5 and 10 per cent concentrations recorded 59.26 and 70.37 per cent larval mortality. Ten per cent aqueous solution found significantly superior over its lower dosage of 5 per cent. Strychnine 5 and 10 per cent aqueous extract recorded 48.14 and 66.66 per cent mortality, respectively. Here also 10 per cent aqueous solution found statistically superior over 5 per cent dose.

Among two fungal pathogens, *M. anisopliae* with 4×10^8 conidia found superior over its lower dosage 2×10^8 conidia (14.81%).

B. brongniartii with 2×10^8 and 4×10^8 conidial doses recorded 14.81 and 22.22 per cent mortality and both the treatments differed statistically with each other.

4.3.2 Evaluation of bioagents and plant products against arecanut root grub, *L. lepidophora* under field condition

Results obtained in the field evaluation of bioagents and plant extracts against arecanut root grub are presented below (Plate 6 and 7).

Table 12: Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under laboratory condition

Sl. No	Treatments	% Larval mortality				
		7DAT	14 DAT	30 DAT	45 DAT	60 DAT
1	<i>Metarrhizium anisopliae</i> with 2X10 ⁸ conidia	0.00 (0.00)g	0.00 (0.00)f	11.11 (19.46)g	11.11 (19.46)f	14.81 (22.34)h
2	<i>Metarrhizium anisopliae</i> with 4X10 ⁸ conidia	0.00 (0.00)g	0.00 (0.00)f	18.52 (25.23)e	22.22 (28.11)e	33.33 (35.24)f
3	<i>Beauveria brongniartii</i> with 2X10 ⁸ conidia	0.00 (0.00)g	0.00 (0.00)f	11.11 (19.46)g	11.11 (19.46)f	14.81 (22.34)h
4	<i>Beauveria brongniartii</i> with 4X10 ⁸ conidia	0.00 (0.00)g	0.00 (0.00)f	14.81 (22.34)f	18.52 (25.23)e	22.22 (28.11)g
5	Aqueous Strychnine seed extract 5%	22.22 (28.11)f	33.33 (35.24)e	44.44 (41.78)d	48.14 (43.91)d	48.14 (43.91)e
6	Aqueous Strychnine seed extract 10%	33.33 (35.24)e	40.74 (39.60)d	59.25 (50.34)c	62.96 (52.52)c	66.66 (54.70)c
7	Aqueous mixture of Soap nut and neem oil 5%	40.74 (39.60)d	44.44 (41.78)c	55.55 (48.16)c	59.26 (50.34)c	59.26 (50.34)d
8	Aqueous mixture of Soap nut and neem oil 10%	44.44 (41.78)c	55.55 (48.16)b	66.67 (54.70)b	70.37 (59.07)b	70.37 (57.07)c
9	Chlorpyrifos 20EC @ 1.2%	62.96 (52.52)a	74.07 (59.45)a	88.89 (70.45)a	88.89 (70.45)a	88.89 (70.45)a
10	Phorate 10G @ 2.5 %	51.84 (46.03)b	55.55 (48.16)b	70.37 (57.07)b	74.07 (59.45)b	77.77 (61.82)b
11	Untreated Control	0.00 (0.00)g	0.00 (0.00)f	0.00 (0.00)h	0.00 (0.00)g	0.00 (0.00)i

Figures in the parentheses are arc sine values
Means showing similar alphabets do not differ significantly
DAT – Days After Treatment

Seven days after treatment

The mortality of root grubs after seven days of treatment ranged from zero to 46.67 per cent. Among all the treatments, the highest mortality of 46.67 per cent was recorded in treatment with chlorpyrifos 20 EC @ 6 ml/palm (Table 13). Chlorpyrifos 20 EC @ 6ml/palm was significantly superior over all other treatments. This was followed by phorate 10 G with 33.33 per cent mortality.

Among plant extracts, aqueous strychnine seed extract 5 per cent recorded 10.00 per cent mortality which was on par with aqueous strychnine seed extract at 10 per cent (11.67%). Another plant product, mixture of soap nut and neem oil at 5 and 10 per cent recorded 15.00 and 16.67 per cent larval mortality, respectively.

Among two fungal pathogens, *M. anisopliae* with 2×10^8 conidia/g at 10 g and 20 g doses recorded no mortality of root grubs at 7 days after treatment. *B. brongniartii* with 2×10^8 conidia/g at doses of 10 and 20 g per tree also recorded no mortality of root grubs at 7 days after treatment (Table 13).

Fourteen days after treatment

After 14 days of treatment, the mortality of root grubs, among all the treatments mean per cent larval mortality ranged from zero to maximum of 66.67 per cent. The highest mortality was recorded in treatment with Chlorpyrifos 20 EC at dose 6 ml per tree. This treatment was significantly superior over all other treatments. Phorate 10 G @ 25 g per tree recorded larval mortality of 56.67 per cent.

Among plant products, aqueous mixture of soap nut and neem oil at 5 and 10 per cent concentrations recorded 18.33 and 25.00 per cent larval mortality, respectively. Ten per cent mixture was significantly superior over 5 per cent mixture.

Aqueous Strychnine seed extract at 5 and 10 per cent recorded 13.33 and 16.67 per cent larval mortality, respectively and found on par with each other.

Among the mycopathogens, *M. anisopliae* with 2×10^8 conidia/g @ 20 g/tree showed 6.67 per cent larval mortality and found superior over its lower dose of 10 g per tree with no larval mortality. *B. brongniartii* with 2×10^8 conidia/g treatments with 10 g and 20 g per tree were found on par with each other and recorded no larval mortality at 14 days after treatment.

Thirty days after treatment

At 30 days of treatment the larval mortality was ranging from zero to highest of 81.67 per cent. The highest mortality was brought by treatment of Chlorpyrifos 20 EC@ 6 ml per tree. This treatment stood significantly superior over all other treatments and next best treatment was phorate 10 G @ 25 g per tree which recorded 70.00 per cent larval mortality (Table 13).

In plant extracts, aqueous mixture soap nut and neem oil 10 per cent showed higher per cent mortality (56.67) and significantly superior over its lower dose of 5 per cent which recorded 46.67 per cent larval mortality. Both the aqueous Strychnine seed extract treatments with 5 and 10 per cent were on par with each other and recorded 30.00 and 36.67 per cent larval mortality respectively.

Among the mycopathogens, *M. anisopliae* with 2×10^8 conidia/g @ 20 g per tree found superior (13.33%) over other fungal pathogen treatments (0.00). Another fungal pathogen *B. brongniartii* was found ineffective at both the levels of conidial concentration and recorded no larval mortality even at 30 days after treatment.

Forty five days after treatment

At 45 days after treatment, the mean per cent larval mortality was ranging from zero to maximum of 83.33 per cent. The highest mortality was achieved by treatment of chlorpyrifos 20 EC @ 5 ml per tree (83.33%). This treatment rose significantly superior over all other treatments and next best treatment was phorate 10 G @ 25 g per tree which recorded 73.33 per cent root grub mortality (Table 13).

Among plant products, aqueous mixture of soap nut and neem oil at 5 and 10 per cent concentrations recorded 50.00 and 58.33 per cent larval mortality and both the treatments were statistically on par with each other.

Aqueous Strychnine seed extract at 5 and 10 per cent aqueous solution recorded 33.33 and 40.00 per cent larval mortality respectively and found on par with each other.

Among the mycopathogen, *M. anisopliae* with 2×10^8 conidia per g @ 20 g per tree showed 20.00 per cent mortality and found superior over its lower dose of 10 g per tree with no larval mortality.

Table 13: Evaluation of bio agents and plant products against arecanut root grub, *L. lepidophora* under field condition

Sl. No	Treatments	Per cent larval mortality				
		7 DAT	14 DAT	30 DAT	45 DAT	60 DAT
1	<i>Metarrhizium anisopliae</i> with 2X10 ⁸ conidia/ g @ 10 g per palm	0.00 (0.00)e	0.00 (0.00)g	0.00 (0.00)g	0.00 (0.00)h	3.33 (8.61)g
2	<i>Metarrhizium anisopliae</i> with 2X10 ⁸ conidia/ g @ 20 g per palm	0.00 (0.00)e	6.67 (14.77)f	13.33 (21.16)f	20.00 (24.99)e	26.67 (31.06)e
3	<i>Beauveria brongniartii</i> with 2X10 ⁸ conidia/ g @ 10 g per palm	0.00 (0.00)e	0.00 (0.00)g	0.00 (0.00)g	6.67 (14.76)f	8.33 (16.59)f
4	<i>Beauveria brongniartii</i> with 2X10 ⁸ conidia/ g @ 20 g per palm	0.00 (0.00)e	0.00 (0.00)g	0.00 (0.00)g	3.33 (8.29)g	6.67 (12.76)f g
5	Aqueous Strychnine seed extract 5%	10.00 (18.43)d	13.33 (21.33)e	30.00 (34.22)e	33.33 (35.24)d	33.33 (35.24)d e
6	Aqueous Strychnine seed extract 10%	10.00 (19.88)d	16.67 (24.04)d e	36.67 (37.21)e	40.00 (39.20)d	40.00 (39.20)d
7	Aqueous mixture of Soap nut and neem oil 5%	15.00 (22.78)c	18.33 (25.29)d	46.67 (43.07)d	50.00 (45.94)c	50.00 (45.94)c
8	Aqueous mixture of Soap nut and neem oil 10%	16.67 (24.04)c	25.00 (28.84)c	56.67 (48.82)c	58.33 (49.78)c	58.33 (49.78)c
9	Chlorpyrifos 20EC @ 6 ml /palm	46.67 (43.07)a	66.67 (54.73)a	80.00 (64.67)a	83.33 (65.93)a	83.33 (65.93)a
10	Phorate 10G @ 25 g /tree	33.33 (34.22)b	56.67 (48.82)b	70.00 (57.89)b	73.33 (58.91)b	73.33 (58.91)b
11	Untreated Control	0.00 (0.00)e	0.00 (0.00)g	0.00 (0.00)g	0.00 (0.00)h	0.00 (0.00)h

Figures in the parenthesis are arc sine values
Means showing similar alphabets do not differ significantly
DAT – Days After Treatment

B. brongniartii with 2×10^8 conidia/g treatments with 10 g and 20 g per tree recorded 3.33 and 6.67 per cent mortality respectively. *B. brongniartii* with 2×10^8 conidia/g at dosage of 20 g per tree was found significantly superior over its lower dosage of 10 g per tree.

Sixty days after treatment

At 60 days after treatment the larval mortality was ranging from zero to highest of 83.33 per cent. The highest mortality was brought by treatment of Chlorpyrifos 20 EC @ 6 ml/tree. This treatment stood significantly superior over all other treatments and next best treatment was phorate 10G @ 25 g per tree which recorded 73.33 per cent larval mortality (Table 13).

In case of plant extracts, soap nut and neem oil aqueous mixture at 5 and 10 per cent concentrations recorded 50.00 and 58.33 per cent larval mortality and found on par with each other.

Aqueous Strychnine seed extract 5 and 10 per cent recorded 33.33 and 40.00 per cent larval mortality respectively and found on par with each other at 60 days after treatment.

Among two fungal pathogens, *M. anisopliae* with 2×10^8 conidia per gram at 20 g per tree found superior over its lower dose (3.33%) and can be comparable Strychnine seed extract at 5 per cent. *B. brongniartii* with 2×10^8 conidia/g at 10 g and 20 g were on par with each other recorded 8.33 and 3.33 per cent mortality respectively.

5. DISCUSSION

5.1 POPULATION DENSITY OF DIFFERENT STAGES OF ARECANUT ROOT GRUB, *Leucopholis lepidophora* IN UTTARA KANNADA AND SHIMOGA DISTRICT

Survey in root grub menace areas of Uttara Kannada and Shimoga districts revealed that the average number of eggs varied from 0.00 to 1.04 per palm during August. The average number of first instar grubs varied from 0.0 to 0.12 per palm during August to October. The mean number of second instar grubs varied from 0.00 to 1.00 per palm during August to January. The third instar grubs are the infesting stage and their mean number of population varied from 4.56 to 0.08 per palm during August to March. Among all taluks surveyed Sirsi and Thirthahalli showed higher late instar larval count. Grub count reduced from August (Sirsi 4.64 and Thirthahalli 5.40 grubs per palm) to March (Sirsi 0.32 and Thirthahalli 0.08 grubs per palm) by this it is evident that both the taluks were more endemic areas for root grub (Fig. 3-7). The mean number of pupae and adults per palm varied between 0.00 to 0.04 and 0.00 to 0.96 respectively during August. During all the four rounds of survey the low population of pupal stage may indicate that larval period is extending for longer periods and the depth of sampling was only 60 cm and pupal stages might be still below this depth. Kumar (1997) reported that pupae and teneral adults of *L. lepidophora* were found at 30-130 cm depth below the soil surface. Depth of availability of all stages, dependent on soil moisture content of the garden. Also present findings are in confirmation with Mishra and Singh (1993) who reported that eggs and 1st instar larvae of *Holotrichia longipennis* Blanch. were found during June to August, with 2nd and 3rd instar larvae damaging potato tubers found at the end of July and mid August, respectively. Larvae migrated downwards in the soil at the end of October and overwintered in a quiescent stage. Patil and Adsule (1991) who reported that all the stages of *Leucopholis lepidophora* were present in August. Eggs were found in August to October, 1st instar larvae in February to October, pupae and adults in June to October. Since 2nd and 3rd instar larvae are the only damaging stages in sugarcane and these were observed in February to June.

Oyafuso *et al.* (2002) who reported that eggs and first stadium larvae of *Dasylepida* spp. were found during April-June. Second stadium larvae were encountered during June to August. Third stadium larvae were encountered during August to November in a sugarcane field of Miyako Island. Chandel *et al.* (2003) who reported large number of *Brahmina coriacea* of all stages during soil sampling. Pupae were found in the soil during April followed by adults and eggs during May and June to July, respectively. The larvae were in the soil from July to April. The third instar grubs infested the crops in September to October and overwintered in the soil up to April. Padmanaban and Daniel (2003) who reported that, first instar grubs of *L. burmeisteri* were noticed in the soil up to 2nd week of September, second instar grubs up to December 2nd week and third instar grubs found up to March in arecanut ecosystem. Channakeshava (2006) reported that eggs and 1st instar grubs of *L. lepidophora* were observed from August to September. Second and third instar grubs were found from May to October. Both pupae and adults were found during June to October in Arecanut ecosystem.

5.1.1 Depth of larval availability in arecanut ecosystem

In all the four rounds of survey (August 2006 to March 2007) in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli the depth of larval availability near root zone ranged from 18.6 to 60 cm, 19.4 to 60 cm, 18.2 to 60 cm, 18.6 to 60 cm and 15.8 to 60 cm, respectively in each taluk. Grubs were encountered in a lower depth when there was high soil moisture than in low soil moisture condition. These results are in confirmation with Nigam and Awasthi (1978) who studied larval, pupal and adult populations of *H. consanguinea* (Blanch) at various depths. According to them adults being active only with the onset of rainfall in May-June. When inactive, the adults were commonly found at a depth of 30-70 cm, depending on the soil moisture content. Larvae were found at 0-75 cm from May to October and pupae at 25-10 cm from October to January. Kumar (1997), who reported that eggs of *L. lepidophora* was observed 15-90 cm below the soil surface. Whereas I, II and III instar larvae were found 0-80, 10-80 and 0-90 cm depth below the soil surface, respectively. Pupae and teneral adult were

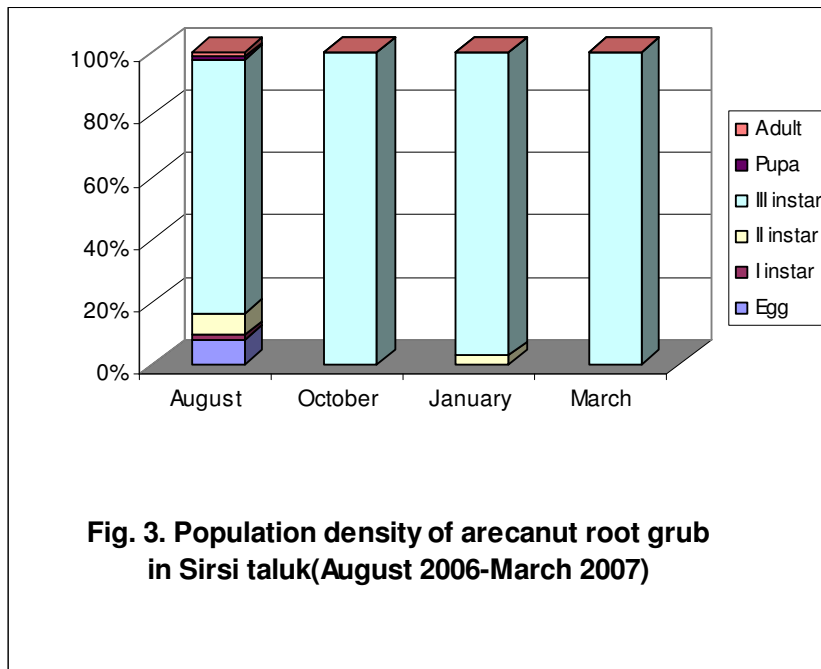


Fig. 3. Population density of arecanut root grub in Sirsi taluk(August 2006-March 2007)

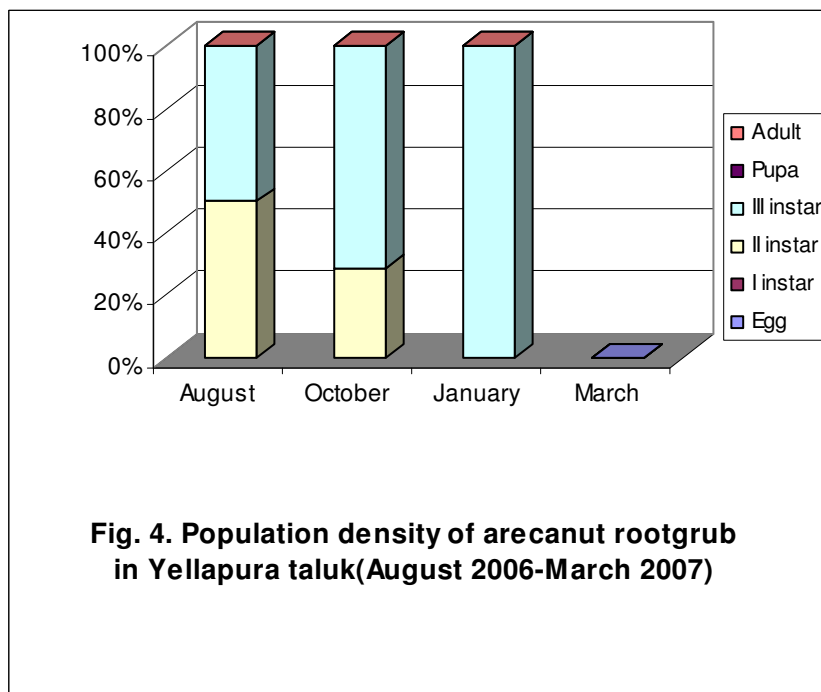


Fig. 4. Population density of arecanut root grub in Yellapura taluk(August 2006-March 2007)

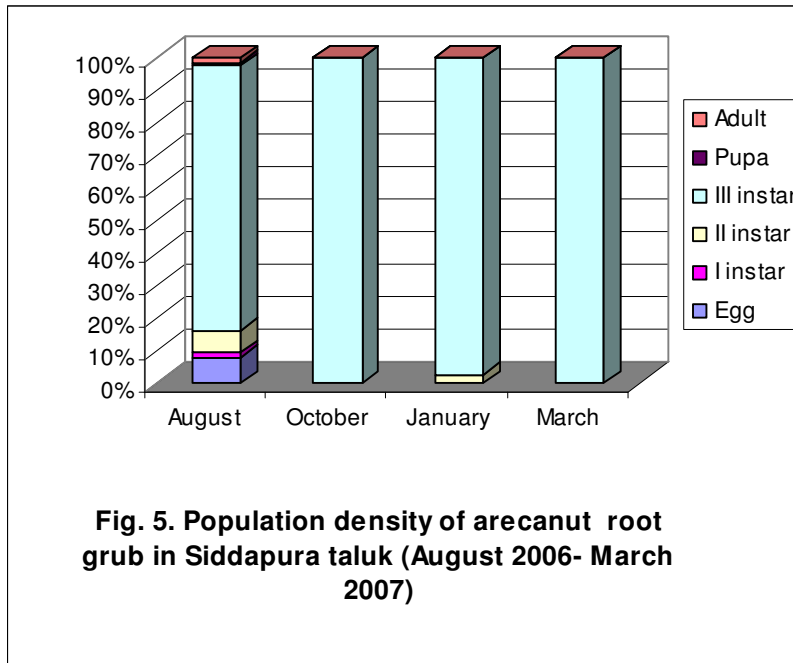


Fig. 5. Population density of arecanut root grub in Siddapura taluk (August 2006- March 2007)

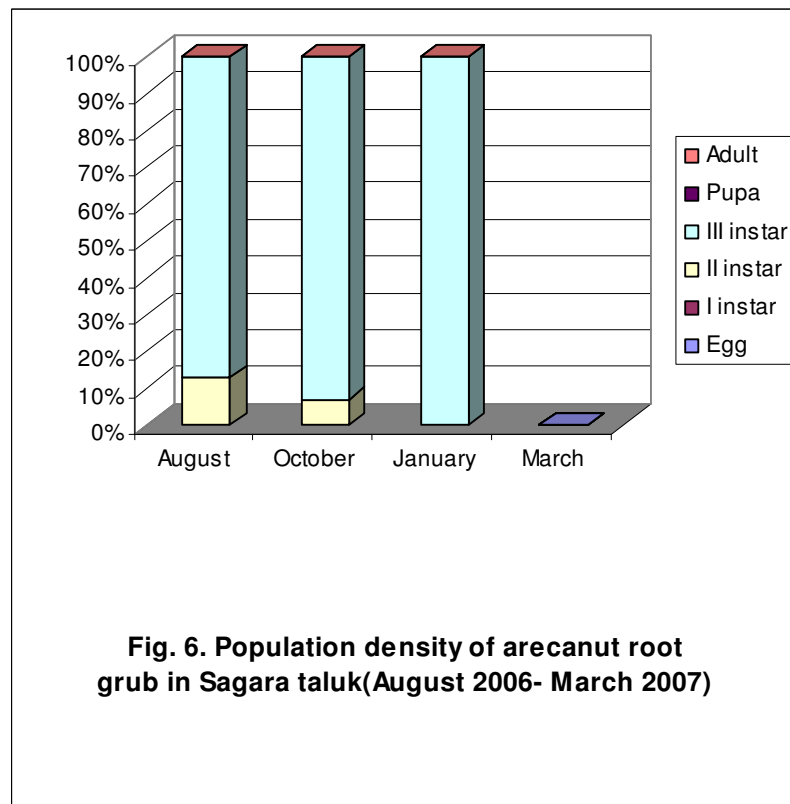


Fig. 6. Population density of arecanut root grub in Sagara taluk(August 2006- March 2007)

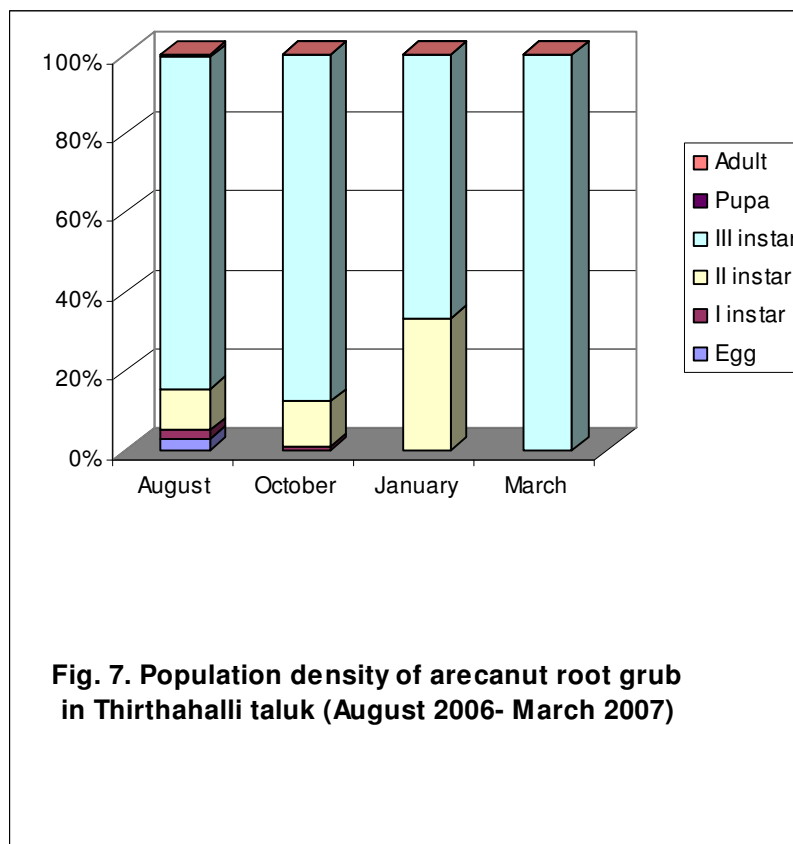


Fig. 7. Population density of arecanut root grub in Thirthahalli taluk (August 2006- March 2007)

found at 30-130 cm depth below the soil surface. Depth of availability of all stages, dependent on soil moisture content of the garden.

5.1.1 Studies on species identification of arecanut root grub

Taxonomic identification of arecanut root grub from all surveyed taluks revealed that *Leucopholis lepidophora* Blanch was a predominant species in all root grub infested areas of Uttar Kannada and Shimoga districts. A perusal of available literature revealed some information about species complexity is as follows.

Veeresh *et al.* (1982) *L. burmeisteri* and *L. lepidophora* were the major pest of arecanut, widely distributed in Kerala and Western ghats of Karnataka. Gangwar (1988) who reported that *H. longipennis* was a predominant species caught in light trap about 98.33 per cent in research farm of ICAR research complex in farming system research project site. Forschler and Gardner (1991) who reported that *Cyclocephala* spp. were the predominant species caught in the light trap study conducted in Georgia, USA. Mishra and Singh (1997) who reported that fourteen, species of Scarabaeids were trapped in light traps out of which *A. dimidiata* was the predominant one. Kumar (1997) who reported that *L. lepidophora* was found distributed throughout the hilly areas covering Uttara Kannada, Dakshina Kannada, Shimoga and Chikmagalur districts of the state. This accounts for 58.3 per cent of total area visited and 88.15 per cent arecanut gardens were infested with white grub.

5.1.3 Influence of rainfall on root grub population

In all surveyed taluks, rainfall had a positive effect on grub population in Sirsi $Y = -0.0001X^2 + 0.0845x + 0.98$, ($R^2 = 0.9162$), Siddapura $Y = -6E-06X^2 + 0.0065X + 0.66$ ($R^2 = 0.7204$), Yellapura $Y = -9E-06X^2 + 0.0063 + 0.06$ ($R^2 = 0.9591$), Sagara $Y = -4E-05X^2 + 0.025X + 0.12$ ($R^2 = 0.9872$) and Thirthahalli $Y = 0.0001X^2 + 0.1112X + 0.16$ ($R^2 = 0.9994$) (Fig. 8-12)

It was also observed that, rainfall not only showed linear relationship with the grub count, but also showed quadratic effect. However quadratic effect is very less compare to

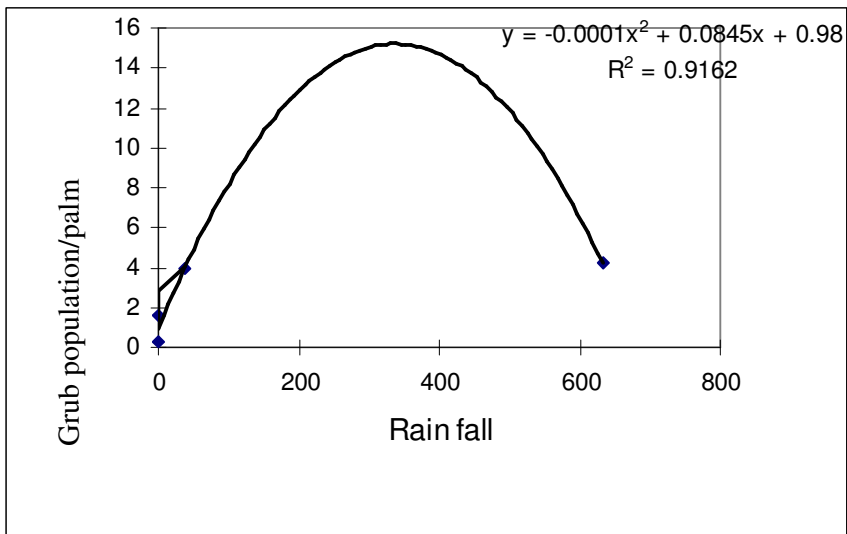


Fig. 8. Influence of rainfall on root grub population (Sirsi)

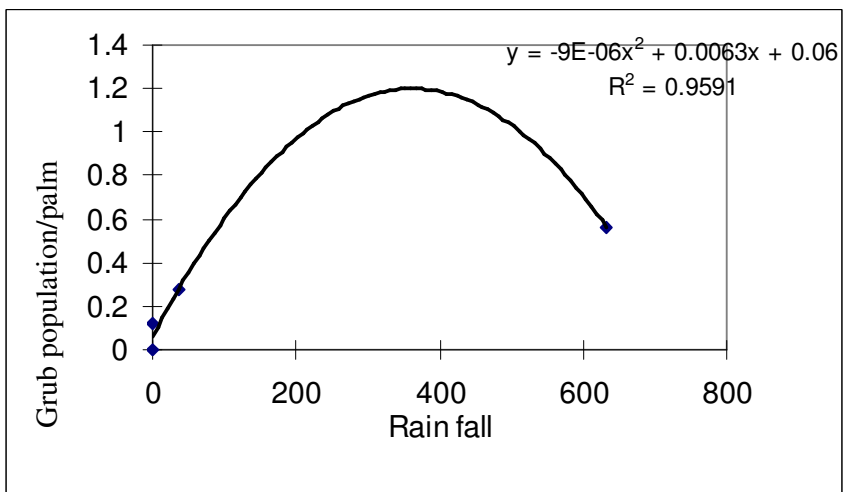


Fig. 9. Influence of rainfall on root grub population (Yellapura)

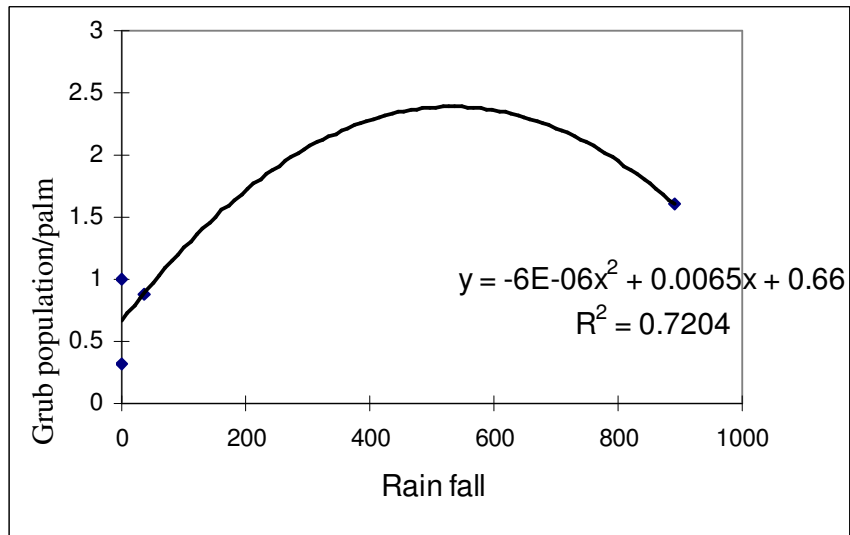


Fig. 10. Influence of rainfall on root grub population (Siddapura)

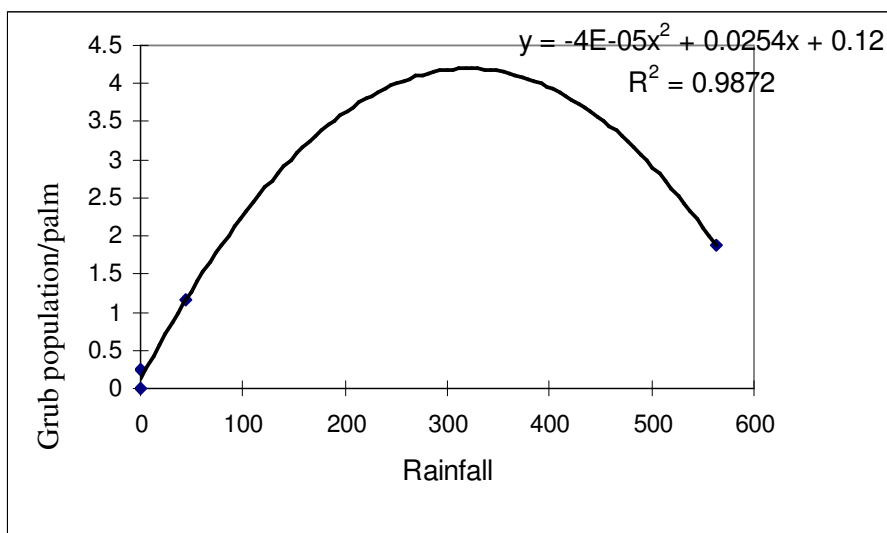


Fig. 11. Influence of rainfall on root grub population (Sagara)

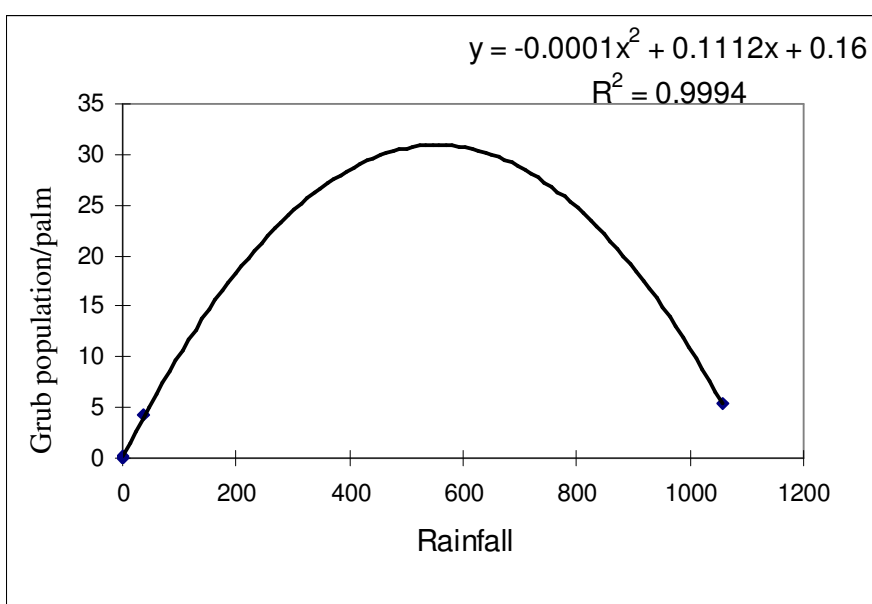


Fig. 12. Influence of rainfall on root grub population (Thirthahalli)

linear effect, it means grub count was more when there was high rainfall, grub count was also observed in low number when there was no rainfall (0.98 grubs in Sirsi, 0.06 in Yellapura, 0.66 in Siddapura, 0.12 in Sagara and 0.16 in Thirthahalli, respectively).

Present findings are in agreement with Veeresh (1977) who reported that low and high moisture content in the soil affected the growth, development and movement of the grubs of *H. serrata*. Saturated soil moisture was required for emergence of beetles. Yadava and Saxena (1977) who reported that sufficient rain required for emergence of beetles. Drought during monsoon season caused death of beetle in the soil itself. Veeresh *et al* (1982) reported that suitable soil moisture increased the grub (*Leucopholis* spp.) activity in soil. Stagnation of water in the field reduced the grub population. High moisture content caused rotting of eggs and death of grubs due to suffocation. Mishra and Singh (1993)

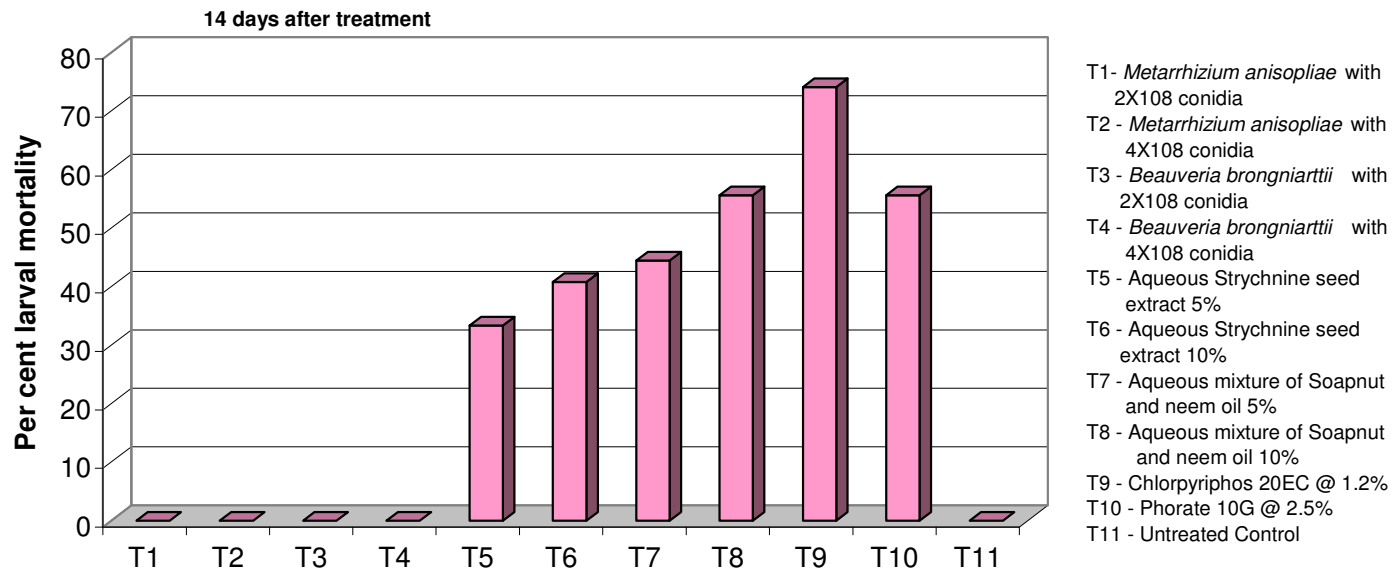


Fig. 13. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under laboratory condition

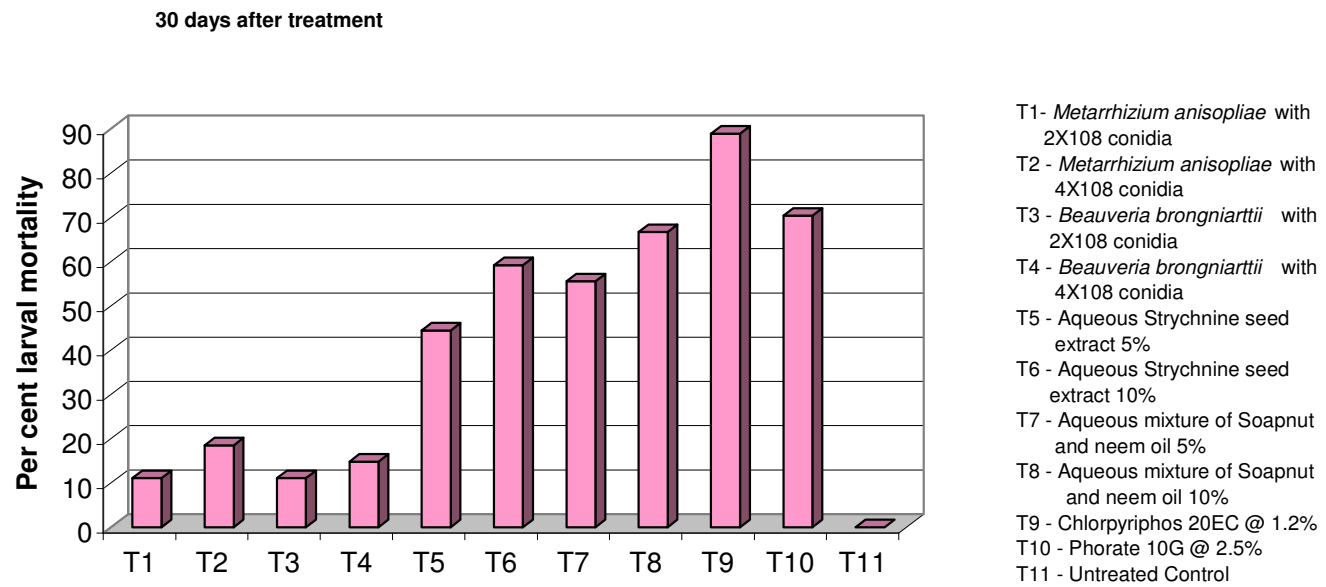
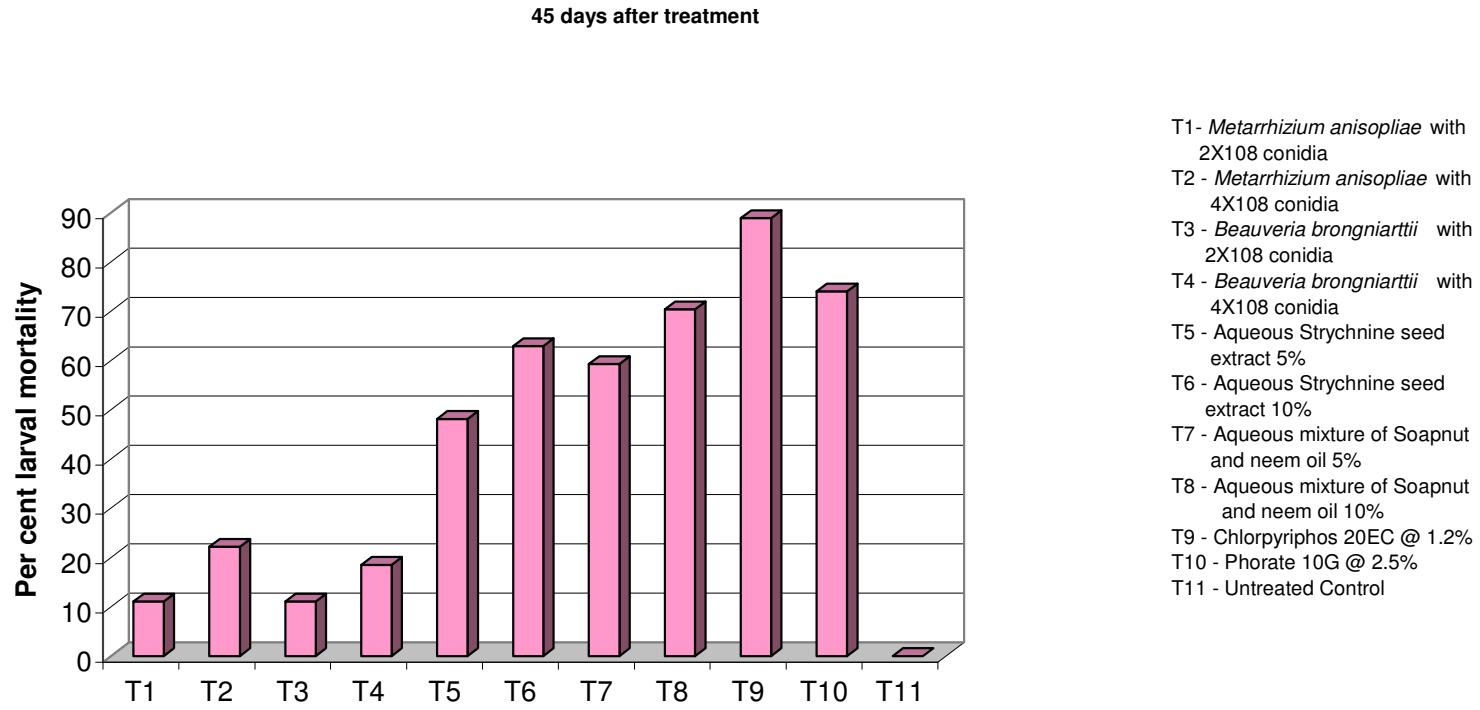


Fig. 13. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under laboratory condition



- T1 - *Metarrhizium anisopliae* with 2X10⁸ conidia
- T2 - *Metarrhizium anisopliae* with 4X10⁸ conidia
- T3 - *Beauveria brongniartii* with 2X10⁸ conidia
- T4 - *Beauveria brongniartii* with 4X10⁸ conidia
- T5 - Aqueous Strychnine seed extract 5%
- T6 - Aqueous Strychnine seed extract 10%
- T7 - Aqueous mixture of Soapnut and neem oil 5%
- T8 - Aqueous mixture of Soapnut and neem oil 10%
- T9 - Chlorpyrifos 20EC @ 1.2%
- T10 - Phorate 10G @ 2.5%
- T11 - Untreated Control

Fig. 13. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under laboratory condition

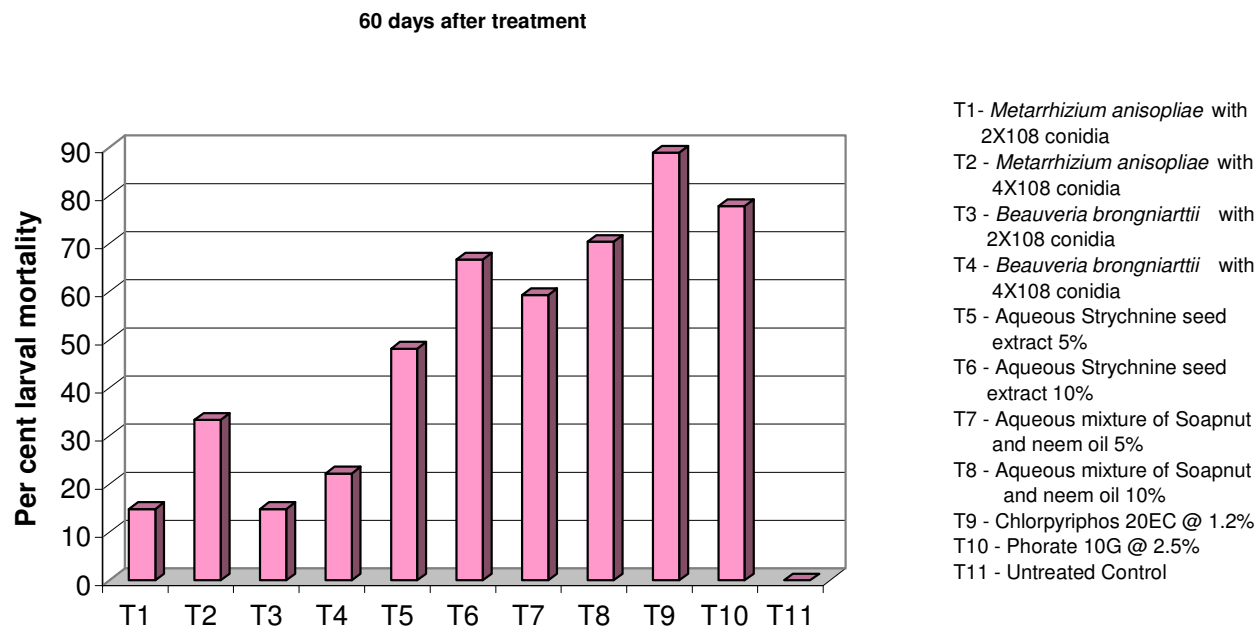


Fig. 13. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under laboratory condition

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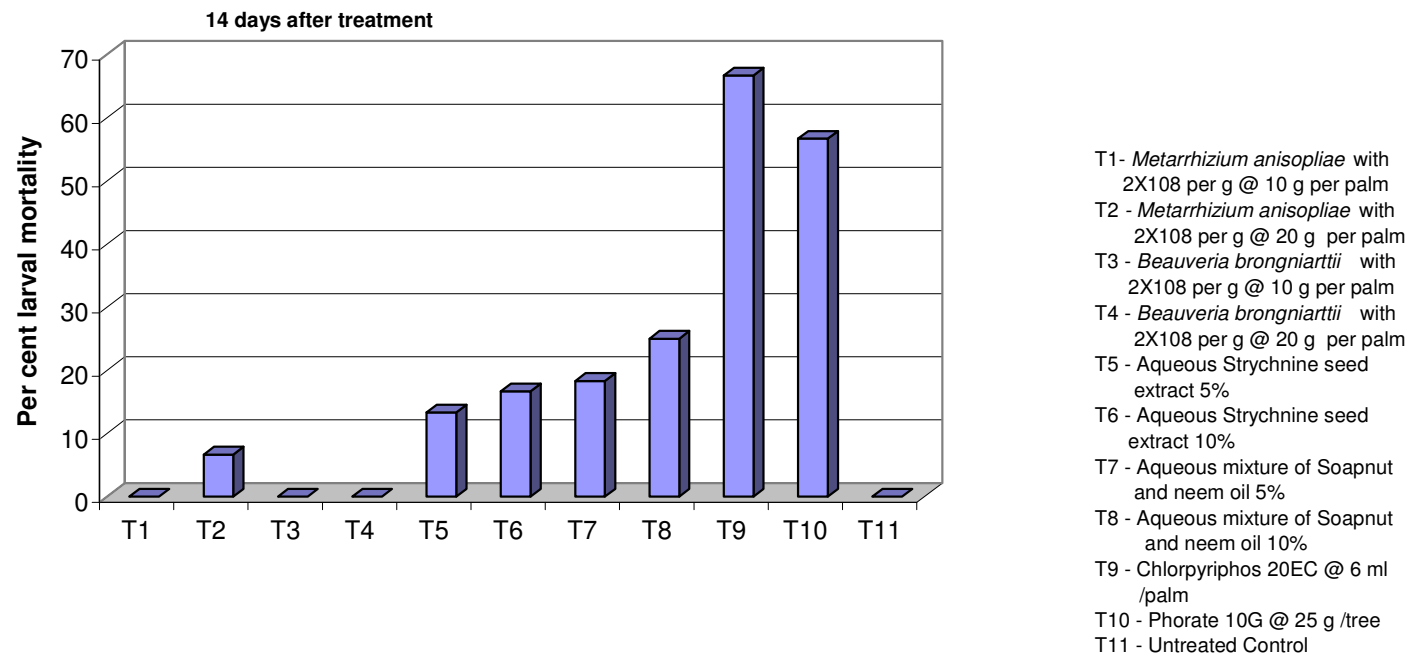


Fig. 14. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under field condition

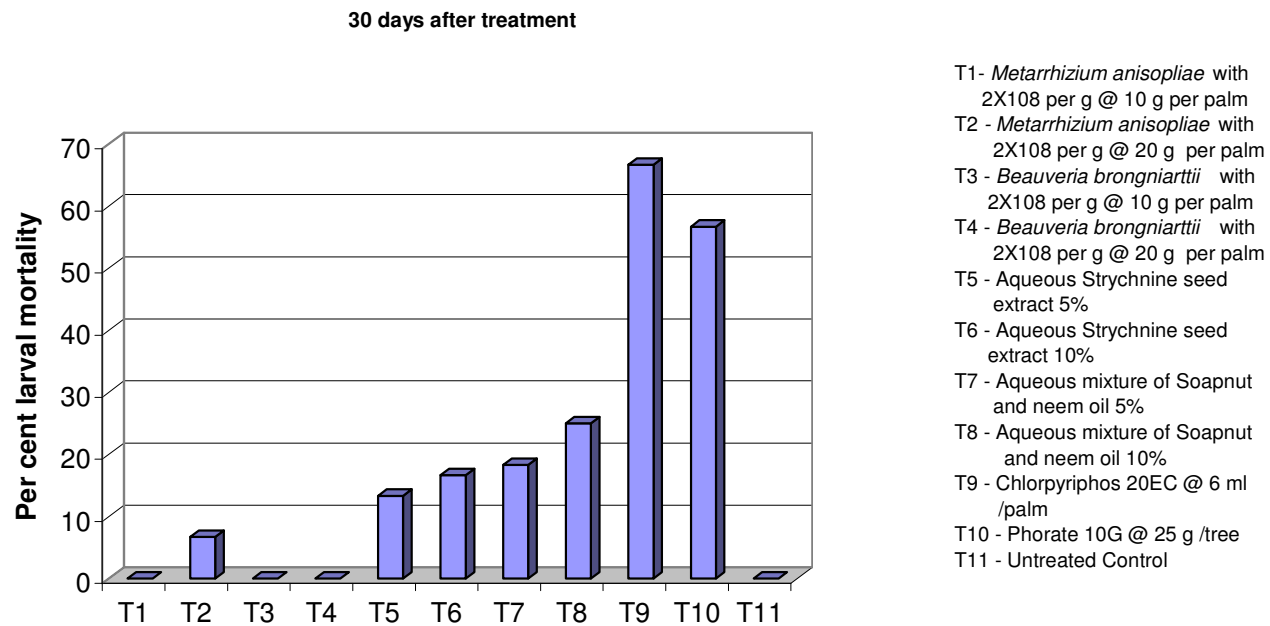


Fig. 14. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under field condition

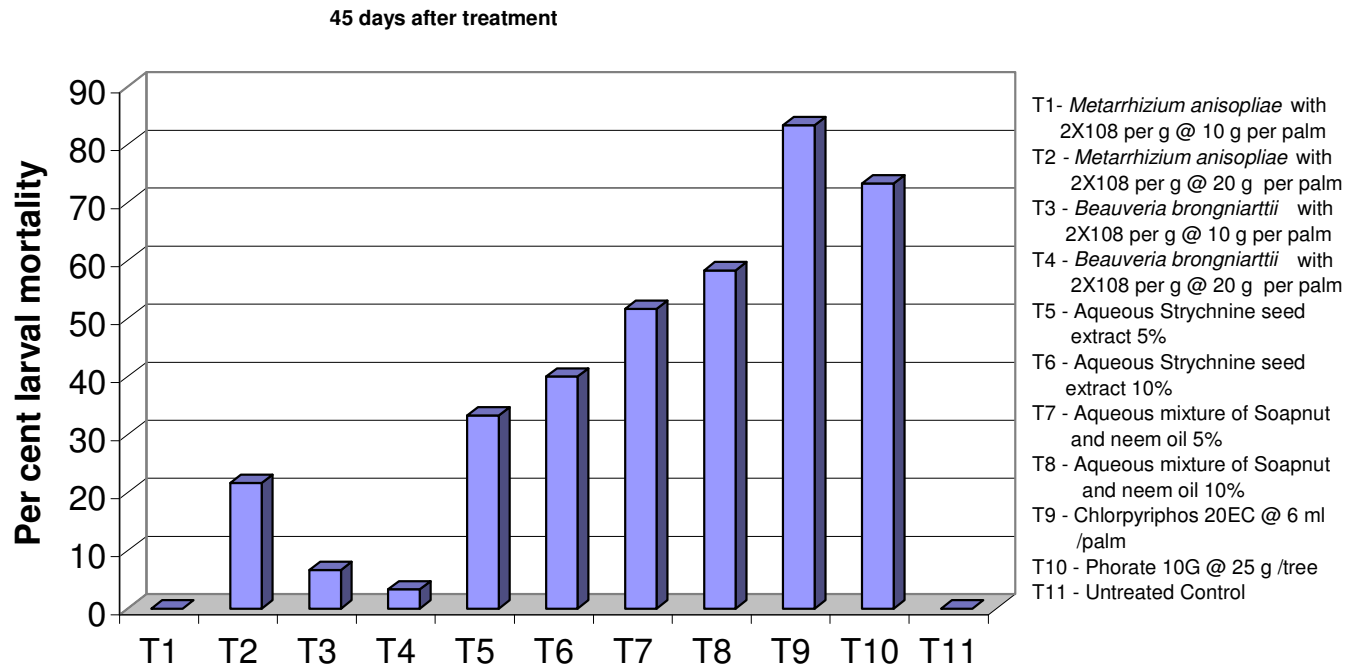


Fig. 14. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under field condition

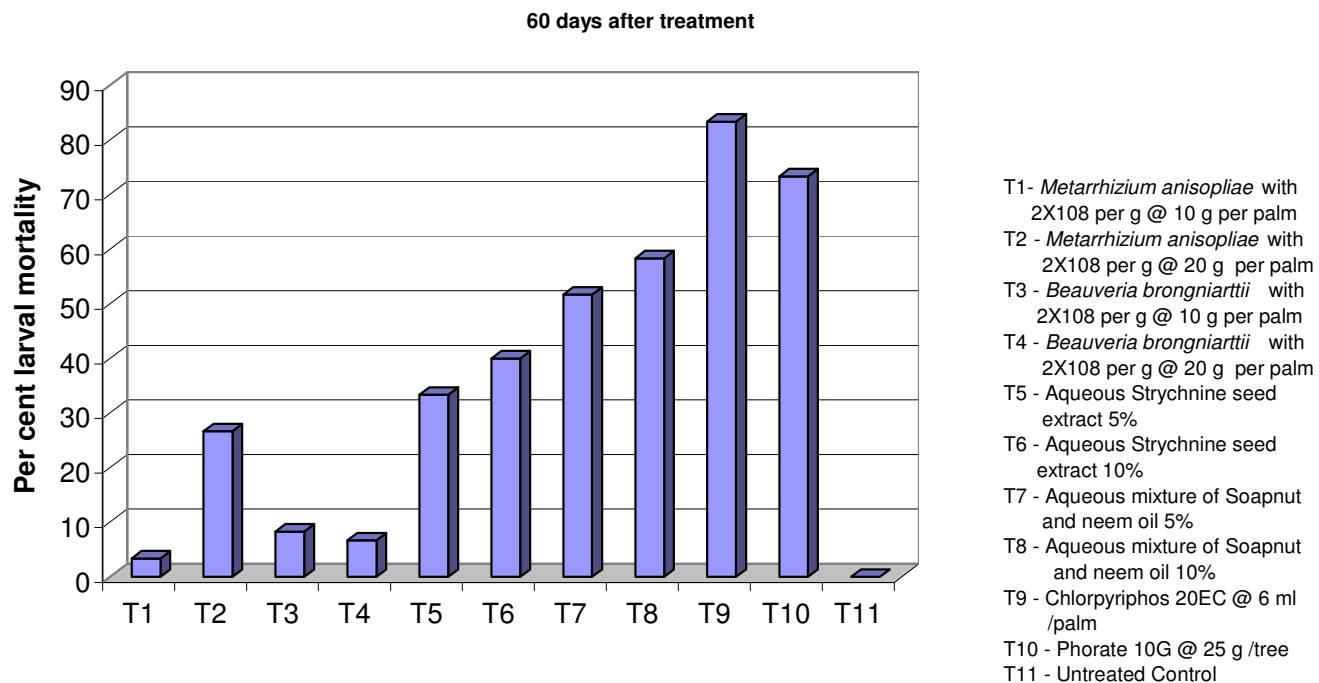


Fig. 14. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under field condition

Fig. 14. Evaluation of bio agents and plant product against arecanut root grub, *L. lepidophora* under field condition

revealed that low moisture caused movement of the grub into deeper layer of soil. Pupation and beetle emergence were also affected. Gupta and Yadava (1993) who reported that moderate soil moisture increase the survival percentage of grubs (*H. serrata*). Kumar (1997) who reported that grubs of *L. lepidophora* tends to be closer to the surface during the monsoon and deeper during other times. Movement to deeper layers may ensure availability of soil moisture until emergence of the adults.

5.1.4 Types of garden and root grub population

Root grub density was more in new and paddy field converted into arecanut gardens. Grub population in different taluk was 5.1, 0.42, 0.42, 1.52 and 4.82 per palm in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli, respectively compare to its counter part old and traditional arecanut garden where grub count was very less. The total grub count recorded per palm in these old garden was 1.10, 0.0 4.5, 0.0 and 0.0 in Sirsi, Yellapura, Siddapura, Sagara and Thirthahalli. Reason behind this might be due to the soils in new and paddy field converted into arecanut garden was more water holding type coupled with poor drainage system, which maintained a moisture level congenial for root grub existence throughout the year near root zone only. It is anticipated that root grub damage may increase in future due to more conversion of paddy field into areca garden. Due to lack of relevant literature the critical discussion is avoided. However, Kumar (1997) who reported that more grub infestation observed in the younger garden with poor drainage condition.

5.1.5 Damage symptoms

In arecanut, root grub found to feed on the terminal tender portion of roots, later move towards bole region and began scooping of bole flesh leads to a deep gash. This profound grazing by grubs cut off the supply of water and nutrient. Prolonged shortage in water and nutrient results in various types of symptoms. Some of the peculiar symptoms are root damage, yellowing, pencilling and toppling. Among the surveyed area these symptoms were more striking in new and paddy field converted arecanut garden, where root damage was a common phenomenon in 60 to 100 per cent visited garden followed by yellowing (ranges from 40 to 85.3 per cent visited garden), pencilling (19 to 80 per cent visited garden) and toppling (0 to 50% visited garden). In contrary, these symptoms were not so common in old and traditional garden where root damage observed in zero to 70 per cent visited garden, yellowing in zero to 32 per cent visited garden, pencilling and toppling in zero to 5 and zero to 3 per cent visited garden respectively. Symptoms were more common in new and paddy field converted as arecanut garden due to more grub load per palm compare to old and traditional garden. This finding is in agreement with Kumar (1997) who reported the root grubs damage in arecanut leads to symptoms like yellowing of leaves which persisted during the rainy season followed by reduced crown region, reduced root anchorage, appearance of pencil head and toppled when pushed. Younger plantations showed more damage symptoms than old gardens.

5.1.6 Adoption of different management practices by farmers in Uttara Kannada and Shimoga districts

During the survey arecanut growers were interviewed to know the management practices adopted by them to tackle the arecanut root grub, based on different management practices adopted by the growers were categorized, among which 64.50 per cent growers adopted chemical control by using insecticides mainly chlorpyrifos 20 EC (3 ml to 12 ml per litre) and phorate 10 G (20 to 50 g per tree). Use of botanical insecticides was accounted for 22.57 per cent (among which 12.90 per cent farmers used neem product), farmers who used mechanical collection of root grubs in the garden recorded 9.67 per cent, only 6.45 per cent of farmers were found using entomopathogenic fungi (mainly *M. anisopliae*), other methods used by farmers included the use of salt (50 to 10 kg/ac) which accounted for 6.42 per cent and 9.20 per cent interviewed farmers left their field as such without any control measures. Present findings are analogues with Gowda *et al.* (1990) they conducted survey of the Scarabaeids *Leucopholis* spp. in arecanut plantation in Karnataka, India. The results indicated that the pests were first noticed in 1964 and 47.12 per cent of plantations were affected by root grub. Control measures adopted by only 20.68 per cent of growers.

5.1.7 Natural enemies of arecanut root grub, *L. lepidophora* recorded in Uttara Kannada and Shimoga districts during the survey in August 2006 to March 2007

A number of natural enemies of arecanut root grubs were observed during the field visits these includes predators, a parasitoid and a pathogen. Among the predators false vampire bat, wild boar and unknown species of garden lizard activities were most evident. In case of parasitoid, cocoon of scoliid wasp found attached to third instar grub. Among the pathogen a mycosed grub was recovered during survey which was later get identified as *Beauveria* sp. Present study is in agreement with study undertaken by Kumar (1997) to record the natural enemies of arecanut root grub showed the predators like wild boar (*Sus cristatus*) two species of crows and a species of bat, among the parasitoid scoliids and Bombyliids were found to parasitise the grubs. Among the entomopathogens, *M. anisopliae*, *Bacillus popilliae*, *B. brongniartii* and nematodes like *S. glaseri* and *Heterorhabditis* spp. are the major ones. Padmanaban *et al.* (2003) under took a survey in arecanut root grub endemic areas to record the natural enemies of white grub. They found bacteria (*Myrothecium* and *Bacillus*), fungi (*Aspergillus*, *Metarrhizium* spp. and *Fusarium* spp.), protozoa (*Pseudomonocystis* spp.), nematodes (Steinernematid and Heterorhabditis), hymenopteran parasitoids (scoliid wasps), dipteran parasitoid (Bombyliids) and Aver (Common crow and bat) as the major natural enemies.

5.2 STUDIES ON YIELD LOSS DUE TO ARECANUT ROOT GRUB

Intervention of protection measures (for one season) in arecanut ecosystem resulted in on an average 8.85 kgs of nuts per palm compare to unprotected condition (7.05 kgs per palm) but statistically both were on par with each other. This might be due to garden selected for yield loss study was infested with root grub long back (more than seven year) the small span control measure (just for 3 month) may not be sufficient to estimate actual yield loss. This need a prolonged study of more than 2 to 3 year and also arecanut being a perennial crop, present yield was result of lost year farm practices this year intervention of protection may show its effect in next year. Due to lack of relevant literature the critical discussion is avoided. However, Gowda *et al.* (1990) reported that survey of the scarabaeid *Leucopholis* spp. in arecanut plantation showed average reduction in yield, which was estimated to be 101.12 kg per acre under severe infestation. Anonymous (1990) who reported that sugarcane white grub feeds on roots causing lodging, reduced plant growth and death of the cane, which holds 75 per cent share among all insect pest losses to sugarcane in Australia. Mishra (1995) reported that *H. coracea* (Hope) was a major pest of potato in Himachal Pradesh. The yield loss due to this pest ranged from 15.5 to 80.0 per cent in prone areas. Padmanaban and Daniel (2003) revealed that arecanut white grub *L. burmeisteri* Brenske was the major pest of arecanut palm in Karnataka and Kerala causing significant yield loss.

5.3 EVALUATION OF BIOAGENTS AND PLANT PRODUCTS AGAINST ARECANUT ROOT GRUB BOTH IN LABORATORY AND FIELD

Out come of laboratory study indicate that, chlorpyrifos 20 EC @ 1.2% proved as the best treatment at all observation intervals (7, 14, 30, 45 and 60 DAT) followed by phorate 10 G @ 2.5%. In case of plant products, aqueous extract of soap nut and neem oil 10 per cent found superior over its lower dosage and also over both the concentration of another plant extract Strychnine seed extract, mixture of soap nut and neem oil at 10 per cent has performed on par that of phorate 10G at 7, 14, 30 and 45 DAT (Fig. 13).

Up to 14 DAT two mycopathogens *M. anisopliae* and *B. brongniartii* at two different dosages did not cause any significant reduction in grub population. As time imposition of treatment was prolonged the effect of mycopathogens was further improved. Among all treatments of mycopathogen, *M. anisopliae* with 4×10^8 conidia showed higher per cent mortality over its lower dose and also over both the dosage *Beauveria brongniartii*.

Outcomes of field study was showed almost similar trend as that of laboratory studies. Here also chlorpyrifos 20 EC @ 6 ml per palm proved as the best treatment at all

observation periods followed by phorate 10 G @ 25 g per tree. In plant extracts, soap nut and neem oil 10 per cent aqueous mixture showed higher per cent mortality, but its effect found almost similar to its lower concentration treatment except 30 DAT (Fig. 14). In case of Strychnine seed extract 10 per cent found on par with its lower concentration treatment throughout the experiment period. Present findings are in analogous with Kumar and Daniel (1981) who reported *L. burmeisteri* infesting arecanut roots can be managed effectively by using dimethoate 5 per cent granules at 30 kg/ha, pongamia oil cake at 2000 kg/ha, chlordane 5 per cent dust at 90 and 120 kg/ha and quinalphos 1.5 per cent dust at 90 and 120 kg/ha. Subaharan *et al.* (1997) who reported that field evaluation of neem cake @ 1000 kg/ha against arecanut root grub *L. lepidophora* caused a mean reduction of 21 and 34 per cent during 1st and 2nd year trail in Sringeri, Karnataka state. Padmanaban *et al.* (1997) who reported that among the commercial available oil cakes and plant products tested against *L. burmeisteri*, Karanj oil cake and leaf powder of *Vitex negundo* treatments gave the highest per cent mortality.

Among the two mycopathogen under study at two different dosages, except *M. anisopliae* with 2×10^8 conidia per gram @ 20 g per tree no other treatment caused mortality of root grub till 30 days after imposition of treatment, but as time advances all mycopathogen treatment showed improved in their performance. At last observation *M. anisopliae* with 2×10^8 conidia per g @ 20 g per palm recorded the mortality similar to that of lower dose of Strychnine seed extract. Low performance of mycopathogen at beginning part of experiment is due to well known fact that mycopathogens required time to invade host, develop itself with in the host to cause mycosis and death of host. Present fishout is in parallel with Milner *et al.* (2002) who reported that *M. anisopliae* var *anisopliae* at the dose of 8.7×10^6 conidia per g peat killed 96 per cent can grubs (*Antitrogus* spp.), 85 per cent of *Lepidiota* spp. and less than 36 per cent of other five species of cane grubs tested after 10 weeks of inoculum. Samson *et al.* (1999) found that the number of white grubs (*Dermolepida* spp.) on sugarcane were consistently reduced by more than 50 per cent when spores of *M. anisopliae* (F1-1045) together with rice medium were applied @ 33 kg per ha. On the other hand a granulated formation of *Metarrhizium anisopliae* (ZBW 9501) when applied @ 8.3×10^{12} conidia per ha had no major impact on the pest and it was concluded that, the poor efficacy of fungus in field mainly because of poor virulence and poor epizootic potentiality of the isolate. Hajeri (2003) who reported that *M. anisopliae* @ 2×10^{13} conidia per ha recorded 60.06 per cent reduction in III instar grub population (60 DAT) in arecanut ecosystem was next best to chlorpyrifos 20 EC drenching @ 5 l/ha. Channakeshava (2006) who reported that *M. anisopliae* 2×10^8 conidia per gram @ 1.1 kg per acre gave 50.97 per cent mortality of *L. lepidophora* in arecanut ecosystem.

From the present findings, it is evident that soap nut and neem oil 5 per cent recorded 51.67 per cent (60 DAT) mortality of III instar grub and found next best treatment after insecticides, followed by aqueous Strychnine seed extract at 5 per cent which recorded 33.33 per cent mortality (60 DAT). Both this botanical can be used in field to combat the pest and both will be effective up to 45 days. Apply these aqueous extracts ones in 1st week of July and Second time during September last week based on grub load in the field.

FUTURE LINE OF WORK

1. More studies on bio-ecology and life table of arecanut root grub can be done.
2. Long duration (three years or more) trials on yield loss studies are required for accurate yield loss estimation.
3. Economic Threshold Level for arecanut root grub can be worked out.
4. Evaluation of other bio agents like Entomopathogenic nematodes and bacteria should be done.
5. Evaluation of other plant products which are in common use against arecanut root grub among the farming community.

6. SUMMARY AND CONCLUSIONS

Results of the investigations carried out during 2006-07 on survey for root grub infested arecanut garden in Uttar Kannada and Shimoga district, estimation of yield loss in arecanut due to root grub, confirmation of *Leucopholis* sp. in these two districts and evaluation of bioagents and plant products against arecanut root grub under laboratory and field conditions are summarized below.

Species of arecanut root grub in five surveyed taluks of Sirsi, Siddapura, Yellapura, Sagara and Thirthahalli was confirmed as *Leucopholis lepidophora* Blanch. which infests arecanut.

Survey from August 2006 to March 2007 in five taluks (Sirsi, Siddapura, Yellapura, Sagara and Thirthahalli) revealed that there was no clear cut generational difference and overlapping generations were seen in all the gardens visited. However, late instar (III instar) was seen in higher numbers as compared to other instars and stages. A typical adult emergence in large numbers was also observed at the end of August month in Siddapura taluk.

Among all taluks surveyed, Sirsi and Thirthahalli showed higher larval count (Sirsi 4.64 and Thirthahalli 5.40 grubs per palm) compared to Yellapura, Siddapura and Sagara taluks.

Population density studies over time revealed that third instar grubs are the infesting stage and their mean number varied from 4.56 to 0.08 per palm during August to March. Grub population reduced from August (Sirsi 4.64 and Thirthahalli 5.40 grubs per palm) to March (Sirsi 0.32 and Thirthahalli 0.08 grubs per palm).

Availability of root grub in root zone (vertical distribution) mainly depends on moisture level of the garden. Grubs tend to be closer to the surface during the monsoon and move deeper during other times.

Area under arecanut plantations surveyed in all the five taluks largely constituted young and paddy field converted gardens than old and traditional gardens. There was higher larval load in paddy field converted gardens and higher is the severity. This may be correlated with ill drainage system of young plantations.

New and paddy field converted into arecanut gardens also showed more striking damage symptoms like root damage, yellowing, pencilling and toppling than old and traditional arecanut gardens.

Most of the farmers interviewed were using chemical insecticides (Chlorpyrifos 20EC and Phorate 10G) to combat this pest followed by locally available botanical insecticides namely neem products and rarely soap nut and strychnine plant products. During the course of study, activities of natural enemies recorded include false vampire bat, wild boar, garden lizard, scoliid parasitoid and a mycopathogen (*Beauveria* sp.) were observed.

Intervention of plant protection measures recorded higher nut yield over unprotected condition. However, short span studies did not show significant variation between protected and unprotected condition.

Among the fungal pathogen and plant products evaluated against arecanut root grub, 5 and 10 per cent aqueous mixture of soap nut and neem oil showed significantly higher per cent mortality compared to aqueous extracts of strychnine seeds (5 and 10 per cent) and also over both the fungal pathogens. Soap nut and neem oil mixture has performed the next best treatment after comparative check Phorate.

Both the fungal pathogens (*M. anisopliae* and *B. brongniartii*) exhibited slower action on arecanut root grub and effectiveness was seen only after 60 days. *M. anisopliae* 2×10^8 conidia/g @ 20 g per palm was superior over its lower dose of 10 g per palm. *B. brongniartii* performed equally at both concentrations (10 and 20 g per palm) and found inferior among all other treatments.

Hence, for the management of arecanut root grubs the most eco friendly approach can be the use of plant product like the aqueous mixture of Soap nut and neem oil at 5 per

cent concentration. Arecanut root grub menace can be further tackled by proper moisture management in the gardens by sufficient drainages.

REFERENCES

- Anonymous, 1967, *Annu. Rep. Central and Regional Arecanut Research Stations*, (1964-65). Central Arecanut Research Station, Vittal, India. p.92.
- Abraham, V.A. and Kurian, C., 1970, Save your coconut palms from the ravages of white grub. *Coco. Bull.* **1**(1): 3-4.
- Anonymous, 1990, Scarabaeid larvae control in sugarcane using *Metarrhizium anisopliae*. *J. Invert. Path.* **55**: 135-137.
- Braza, R.D., 1990, Laboratory evaluation of *Metarrhizium anisopliae* (Metsch.) Sorkin against *Leucopholis irrorata* (Chevrolat) (Coleoptera: Scarabaeidae). *Phillip. Ent.* **8**(1): 671-675.
- Balasimha, D. and Rajagopal, V., 2003, Pests In *Arecanut*, Ed. Ponnamma, K.N. and Subaharan, K., CPCRI. Kasaragod. pp.190-223.
- Bhagat, R.M. Gupta, R.B.L. and Yadava, C.P.S., 2003, Field efficacy of two entomopathogenic fungal formulations against white grubs in Himachal Pradesh. *Indian J. Ent.* **65**(1): 76-81.
- Chandel, R.S., Gupta, P.R. and Thakurm, J.R., 1997, Host preference and seasonal abundance of defoliating beetles infesting fruit trees in mid hills of Himachal Pradesh. *J. Soil Biol. and Ecol.* **17**(1): 140-146.
- Chandel, R.S., Chandla, V.K. and Ashwani Sharma, 2003, Population dynamics of potato white grubs in Shimla hills. *J. Potato Assoc.* **30**(1-2): 151-152.
- Chirame, B.B., Khadatare, R.M. and Bhoi, P.G., 2003, Control of white grub (*Holotrichia serrata* F.) in sugarcane with *Beauveria brongniartii*. *J. Maharashtra Agric. Uni.* **28**(2): 208-209.
- Channakeshava, A., 2006, Bio-ecology and management of arecanut root grubs with special reference to *Leucopholis lepidophora* Blanch. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bangalore(India).
- Coleman and Rao, 1918, The cultivation of arecanut palm in Mysore. Dept. of Agril. Mysore State, Bangalore, p.32.
- *Forschler, B.T. and Gardner, W.A., 1991, Flight activity and relative abundance of phytophagous Scarabaeidae attracted to black light traps in Georgia. *J. Agric. Ent.* **8**(4): 179-187.
- Gowda, N.S.S. Balachandra, C.K. and Chakravarthy, A.K., 1990, Incidence of areca white grubs in the hill regions of Karnataka. *Curr. Res.* **19**(5): 79-80.
- Gupta, B.M. and Yadava, C.P.S., 1993, Distribution pattern of white grub *Holotrichia consanguinea* Blanch in semi arid Rajasthan. *Indian J. Ent.* **55**(1): 314-316.
- Gupta, R.B.L., Shashisharma and Yadava, C.P.S., 1998, A simple method for quick evaluation of entomofungi against white grubs. *Indian. J. Ent.* **60**(1): 105-107.
- Hajeri, K.U., 2003, Utilization of *Metarrhizium anisopliae* (Metschnikoff) Sorkin. For the management of root grubs in sugarcane and arecanut. *M.Sc.(Agri.) Thesis*, University of Agricultural Sciences, Dharwad (India).
- Jitender Kumar, Kashyap, N.P. and Chandel, R.S., 1996, Diversity and density of defoliating beetles in Kullu valley of Himachal Pradesh. *Pest Manag.Econ. Zool.* **4**(1): 25-29.
- Kumar, P.T. and Daniel, M., 1981, Studies on the control of soil grubs of arecanut palm. *Pesticide*, **15**(1): 29-30.
- *Krueger, S.R., Villani, M.G., Hartins, A.S. and Roberts, D.W., 1992, Efficacy of soil application of *Metarrhizium anisopliae* (Meteh) Sorkin conidial and standard and lyophilized mycelial particles against scarab grubs. *J. Invert.Path.* **59**: 54-60.

- Kumar, A.R.V., 1997, Bio-ecology and management of arecanut white grubs. *Leucopholis* spp. (Coleoptera: Scarabaeidae) in Karnataka. *Ph.D. Thesis*, Uni. Agric. Sci. Bangalore.
- Mathur, Y.K., Upadhyay, K.D., Srivastava, J.P., Anjor, R. and Agarwal, N., 1989, Survey of white grub beetles in plains of Uttar Pradesh. *Farm Sci. J.* **4**(1-2): 127-130.
- *Milner, R.J., 1990, The selection of strains of *Metarrhizium anisopliae* for control of Australian sugarcane white grubs. *Proceedings of Colloq. Invert. Path. Mic. Control*, Adelaide, Australia, August 20-24. 1990, p.333.
- Mishra, S.S. and Singh, M.P., 1991, Evaluation of some insecticides against the white grub beetle *Holotrichia longipennis* Blanch (Melolonthinae: Coleoptera) damaging apple. *Indian J. Ent.* **53**(4): 594-596.
- Mishra, P.N. and Singh, M.P., 1993, Determination of predominant species of white grub in Kumaon region of UP hills and their control. *Ann. Pl. Prot. Sci.* **5**(2): 154-156.
- Misra, S.S., 1995, White grub, *Holotrichia (Lachnosterna) coracea* (Hope) – A key pest of potatoes in Himachal Pradesh, India. *J. Entol. Res.* **19**(2): 181-182.
- Mohan, C., Vidyasagar, P.S.P.V. and Kumar, K.V., 1997, A sampling techniques to estimate white grub population in coconut garden. *J. Plantation Crops*, **25**(1): 68-71.
- *Milner, R.J., Samson, P.R. and Bullard, G.K., 2002, FI-1045: A profile of a commercially useful isolate of *Metarhizium anisopliae*. *Document Int. Res. Group Wood Preservation*, No IRG-WP-96-10142, p.5.
- Nirula, K.K., 1955, The cock chafer pest of coconut palm. *Indian Coconut Journal*, **8**(1): 8-10.
- Nirula, K.K., Antony, J. and Menon, K.P.V., 1952, A new pests of coconut palm in India. *Indian Coconut J.* **5**(1): 137-140.
- Nirula, K.K., 1958, Investigations on the pests of coconut part V. *Leucopholis coneophora* Burn. *Indian Coconut J.* **12**(1): 10-34.
- Nigam, P.M. and Awasthi, B.K., 1978, Survey of white grub, *Holotrichia consanguinea* Blanch at different depths of soils. *Indian J. Ent.* **40**: 90-91.
- Nair, C.P.R. and Daniel, M., 1982, Pests of arecanut. In: K.V.A. Bavappa, M.K. Nair and T. Premkumar Ed. *The Arecanut Palm (Areca catechu* Linn.) CPCRI, Kasargod (India). pp.162-184.
- Nair, C.P.R. and Devashyam, S., 1982, Pests of coconut and their control. *Indian Cocoa Arecanut and Spice Journal.* **6**(1): 35-36.
- Oyafuso, A., Arakaki, N., Sadoyama, Y., Kishita, M., Kawamura, F., Ishimine, M., Kinjo, M. and Hirai, Y., 2002, Life history of the white grub *Dosylepida* sp. (Coleoptera: Scarabaeidae), a new and severe pest on sugarcane on the Miyako Island, Okinawa. *Appl. Ent. Zoo.* **37**(4): 595-601.
- Puttarudraiah, M. and Cannabasavanna, G., 1957, Some of new insect and mite pests of areca palm in Mysore III. *Arecanut J.* **8**(1): 10-11.
- Patel, K.C., Joshi, D.P., Vyas, H.G. and Yadav, D.N., 1986, Green muscardine disease of white grubs in Gujarat. *Indian J. Mic.* **26**(1-2): 160-169.
- Patil, S.M. and Adsule, V.M., 1991, Population density of different stages of *Leucopholis lepidophora* Blanch infesting sugarcane (Coleoptera : melolonthinae). *Indian Sug.* **41**(1): 169-171.
- Padmanaban, B., Daniel, M. and Srimannarayana, G., 1997, Evaluation of plant material, plant products and oil cakes against arecanut white grubs *Leucopholis burmeisteri* Brenske (Coleoptera: Scarabaeidae: melolonthinae). *Indian J. Pl. Prot.* **25**(2): 121-122.
- Padmanaban, B. and Daniel, M., 2003, Biology and bionomics of palm white grub *Leucopholis burmeisteri*. *Indian J. Ent.* **65**(4): 444-452.

- Rachappa, V., 2004, Occurrence of entomopathogenic fungi and utilization of *Metarrhizium anisopliae* (Metschieff) Sorkin in the management of selected crop pests in north Karnataka. *Ph.D.(Agri.) Thesis*, Uni. Agric. Sci. Dharwad (India).
- Rao, K.S.N., Naidu, G.V.B. and Bavappa, K.V.A., 1961, The white grub pests of arecanut. *Arecanut J.* **12**(1): 22-25.
- Rethinam, P. and Sivaraman, K., 2001, Arecanut (*Areca catechu* L.) present status and future strategies. *Indian Journal of Arecanut Spice and Medicinal Plants*, **3**(1): 35-50.
- *Sekhar, P.S., 1958, Studies on the cock chafer, *Leucopholis coneophora* Burn. A pest on coconut palm and other inter cultivated crops. *Indian Coconut J.* **11**(1): 67-80.
- *Samson, P.R., Mcgill, N.G., Harris, W.J., Milner, R.J., Allsopp, P.G. and Egan, B.T., 1999, Field efficacy of *Metarrhizium anisopliae* as a remedial treatment for negotoria and children's cane grubs. In: *Proceedings 1997 Conference Australian Society of Sugarcane Technology*, Corns, Queensland, 29th April to 2nd May 1997, pp.103-110.
- Sharma, S., Gupta, R.B.L., Yadav, C.P.S. and Sharma, S., 1999, Mass multiplication and formulation of entomopathogenic fungi and their efficacy against white grubs. *Journal of Mycology and Plant Pathology*, **29**(3): 299-305.
- Sadoyama, Y., Oroku, H. and Nakamori, H., 2001, Injury of sugarcane roots by the white grub, *Dasylepida* sp. (Coleoptera : Scarabaeidae), in the Miyako Island. *Japanese J. Appl. Ent. and Zool.* **45**(2): 89-91.
- Subaharan, P.S., Vidyasagar, P.V. and Basheer, M.B.M., 1997, Bio efficacy of insecticides against white grub, *Leucopholis lepidophora* Blanch infesting arecanut palm. *Indian J. Pl. Prot.* **29**(1-2): 25-29.
- Singh, M.P. and Mishra, P.N., 2003, White grubs in hilly and mountain agro ecosystem of Uttaranchal. *Indian Farm*, **1**(1): 20-23.
- Veeresh, G.K., 1977, Studies on the root grubs in Karnataka, with special reference to bionomics and control *Holotrichia serrata* F. (Coleoptera: Melolonthinae). UAS Monograph Series, No. 2, p.87.
- Veeresh, G.K., Vijayendra, M., Reddy, N.V.M. and Rajanna, C., 1982, Bio-ecology and management of arecanut white grubs (*Leucopholis* spp.) (Coleoptera; Scarabaeidae: Melolonthinae). *J. Soil Biol. and Ecol.* **2**(2): 78-86.
- Veeresh, G.K., 1983, White grubs, In: *Applied Soil Biology and Ecology* Ed. G. K. Veeresh and D. Rajagopal (II Edn. 1988). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- *Watt, K.G., 1889, A dictionary of the economic products of India. Vol I. Period, Experts, Delhi, p.559.
- Yadava, C.P.S. and Saxena, R.C., 1977, Bionomics of *Holotrichia consanguinea* Bl. *Indian J. Agric. Sci.* **47**(1): 139-142.
- Yadava, C.P.S., 1991, White grub, management in groundnut. *Tech. Bull.* **1**: 14.
- Yadava, C.P.S. and Sharma, G.K., 1995, Indian white grubs and their management. Indian Council of Agricultural Research, New Delhi. *Technical Bulletin No. 2*, AIC RP on White Grubs, Uni. Agric. Sci. Bangalore. p.26.

* Originals not seen

APPENDIX II. Weather data of Sirsi taluk

2006-2007	Max Temp (oC)	Min Temp (oC)	RH (%)	Rainfall (mm)	No of rainy days	MWV kmph	WD (deg)	CC (Octa)
January(2006)	31.3	13.9	65.2	0.0	0	6.0	111.0	0.50
February (2006)	33.5	12.3	59.6	0.0	0	5.9	112.5	0.00
March(2006)	33.6	16.5	60.1	9.8	2	4.5	207.0	2.40
April(2006)	35.4	20.5	58.5	0.0	0	5.3	264.5	2.67
May(2006)	33.0	21.9	68.3	229.7	5	6.7	270.0	4.95
June(2006)	28.8	23.1	83.5	502.3	18	6.6	266.0	6.70
July(2006)	26.6	23.1	91.1	940.6	30	10.9	279.5	7.90
August(2006)	26.8	22.2	88.45	632.8	22	6.4	290.5	7.45
September(2006)	29.0	22.6	81.65	204.9	11	5.4	250.0	6.30
October(2006)	30.2	21.4	80.45	36.8	4	4.8	166.0	4.48
November(2006)	30.4	20.4	79.15	77.9	3	5.1	109.0	4.10
December(2006)	29.9	15.4	75.80	0.0	0	4.5	91.50	1.76
January(2007)	31.6	15.0	80.95	0.00	0	4.1	103.1	0.5
February(2007)	32.4	15.7	70.05	0.00	0	3.5	137.4	0.45
March(2007)	34.9	20.4	74.00	0.00	0	3.5	181.0	1.60
April(2007)	34.9	22.5	73.65	56.5	2	3.0	225.0	3.6
May(2006)	33.5	21.7	74.95	13.7	1	1.93	255.0	4.75
June(2007)	29.1	21.2	79.8	766.2	21	3.14	259.0	6.98

Salient features of Sirsi Climate

- Total rainfall = 2634.8 mm
- 169.53 mm Excess rainfall over normal
- Maximum rain in July (940.6 mm)
- Lowest temp = 12.3 C in Feb
- Highest temp = 35.4 in April
- Relative humidity ranged from 58.5 to 91.1 %

STUDIES ON ARECANUT ROOT GRUB, *Leucopholis lepidophora* Blanch. AND ITS MANAGEMENT BY ENTOMOPATHOGENIC FUNGI AND PLANT PRODUCTS

RAKESHA H. S.

2007

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ABSTRACT

The arecanut (*Areca catechu*) is an important cash crop of Karnataka and used for masticatory purpose. Arecanut is attacked by several insects and *Leucopholis lepidophora* is the most serious pest causing greater yield reduction. Both laboratory and field studies were conducted with environment friendly plant products and entomopathogens to replace present method of chemical control. Laboratory studies were undertaken in Dept. of Entomology, UAS Dharwad and field studies were conducted in Mavinakoppa Village near Agricultural Research Station, Sirsi.

Field surveys conducted from August 2006 to March 2007 in Uttar Kannada and Shivamogga Districts, comprising Sirsi, Siddapura, Yellapura, Sagara and Thirthahalli. Survey revealed that field population in these taluks consisted overlapping generations and species confirmed as *Leucopholis lepidophora*. However, late instar was seen in higher numbers compared to other instars and stages. Among taluks surveyed, Sirsi and Thirthahalli showed higher larval count (4.64 and 5.40 per palm).

Population density studies revealed that third instar grubs are infesting stage with 4.56 to 0.08 per palm during August to March.

Area under young and paddy field converted into arecanut gardens showed higher grub load and more striking damage symptoms than old and traditional gardens. Parasites and predators of root grub were documented in present study.

Protected trees recorded higher nut yield over unprotected but yield loss study needs to be continued for longer duration.

Among plant products and fungal pathogens, mixture of Soap nut and neem oil 5% recorded 50.00 per cent (60 DAT) mortality of III instar grubs and found next best treatment after insecticides. Among the entomopathogens, *Metarrhizium anisopliae* 2×10^8 conidia per gram @ 20 g per palm recorded 26.67 per cent mortality and found superior over other microbial concentration tested.