K. U. K. Nampoothiri *Editor-in-Chief*
V. Krishnakumar · P. K. Thampan
M. Achuthan Nair *Editors*

The Coconut Palm (*Cocos nucifera* L.) - Research and Development Perspectives

Springer

12.5 Subterranean Pests

12.5.1 Coconut White Grub **Leucopholis coneophora** *Burm. (Coleoptera: Scarabaeidae)*

12.5.1.1 Nature of Damage and Species Complex

White grub, *Leucopholis coneophora* Burm, is a univoltine pest of coconut and intercrops grown in pockets of sandy loam soils in southern parts of peninsular India. It was first reported as a pest of coconut by Nirula et al. (1952). It damages seedlings and adult palms by feeding on roots, boring the bole and collar regions, and severe infestation leads to death of the seedlings. In adult palms, they feed on roots impairing the conduction of water and nutrients and thus lead to yellowing of fronds, gradual shedding and complete yield loss. Survey conducted in Kerala and parts of Karnataka, India, indicated the predominance of *L. coneophora* along the coastal belt, where coconut-based cropping system is practised. It has an annual life cycle and prefers loose sandy soil as noticed by Nirula et al. (1952). Kumar (1997) described it as *L. coneophora* – coastal strain that is occurring at an altitude up to 200 m above MSL. Another species of *Leucopholis* which is morphologically very much similar to *L. coneophora* dominating in coconut gardens of Dakshina Kannada district in Karnataka, India, was described and identified as *Leucopholis burmeisteri* Brenske (Nair and Daniel 1982; Veeresh et al. 1982). According to Kumar (1997), the identified morphological characters by Veeresh et al. (1982) between *L. coneophora* and *L. burmeisteri* were not strong enough to permit the delineation of the two populations up to specific status. Though they exhibited distinct differences in biology, the two populations may be two different etho-species which are difficult to delineate morphologically and can be considered to be two geographical clines. Kumar (1997) designated these two species as *L. coneophora* – coastal strain which occurs at altitude up to 200 m above MSL – and *L. coneophora*, hill strain which occurs at altitude >200 m above MSL. Another species of palm white grub, *L. lepidophora*, is observed to be infesting palms in Western Ghats. *L. lepidophora* larvae and adults are morphologically and biologically distinct from *L. coneophora*. These grubs prefer clayey loam soil (Veeresh et al. 1982; Kumar 1997). Study of phylogenic relation by partial amplification of 16s rRNA and *COI* gene of *L. burmeisteri*, *L. coneophora* and *L. lepidophora* (collected from Dharmasthala, Kasaragod and Sringeri, India, respectively) revealed 98, 83 and 89% similarity, respectively, with *L. burmeisteri sulyareca* isolate, and high resolution melt (HRM) analysis revealed the existence of single nucleotide polymorphism among the three species.

12.5.1.2 Host Range

Leucopholis coneophora is highly polyphagous in nature. Apart from coconut, it feeds on root of arecanut as well as rhizomatous and tuberous intercrops raised in palm garden, viz. banana, colocasia, cassava, elephant foot yam, greater and lesser yams, sweet potato, fodder grasses, etc. It is reported to be feeding on roots of rubber and cocoa also.

12.5.1.3 Bionomics

L. coneophora has annual life cycle and adult emergence coinciding with the setting of south-west monsoon. Emergence occurs daily in the evening hours when luminance fall below 124.37 ± 75.5 lx (around 6.35 pm IST in June) and 1.2 ± 0.4 lx (around 7.10 pm IST), and active swarming is sustained for 3 weeks. On emergence, beetles feed on leaves of weeds, mango, cashew, ficus, etc. Females lay the eggs in interspaces in soil. The eggs have an incubation period of 23 days. Larva is pestiferous and passes through three instars which is prolonged for 260–270 days. First-instar larvae feed on organic matter and roots of grass and are seen at depths of 15–20 cm. They are observed during second half of May to beginning of October. Second-instar grubs are largely distributed at depths of 15–45 cm which could be observed from the first half of July to the first half of November. Late second- and third-instar larvae move towards the root zone and start feeding on palm roots. Third-instar grubs were seen from the first half of the October to the end of July of the succeeding year. With the movement of moisture in soil, larvae move deeper and deeper and subsequently pupate during summer (Abraham 1983). During the next monsoon season aestivating pupae emerge out. During 1976–1978, prolonged adult activity period of 60 days was recorded. Adult emergence initiated during first half of March continued at low level up to second half of May or till early part of June. Scanty emergence continued up to August and September (Abraham 1993). But, more recently a narrow window of adult activity that extended for a maximum period of 3 weeks was noticed in ethological study of *L. coneophora* during 2011–2013 (Prathibha et al. 2013). There has been a huge shift in the emergence pattern of *L. coneophora*. Climate change pertaining to rainfall pattern, distribution and soil temperature could be the major reason for this. A hike in soil temperature (an average increase of 0.22 °C in daily soil temperature from March to September) was noticed during 2011–2013 than those temperature regimes noticed in 1977 and 1978.

12.5.1.4 Integrated Pest Management

An IPM strategy comprising of mechanical, chemical and biological methods is recommended to effectively manage white grubs.

Mechanical: Handpicking and Destruction of Beetle Mechanical capture and destruction of cockchafers between 6.35 pm and 7.15 pm for 2–3 weeks commencing from the first day of monsoon is advisable as a mechanical tool in IPM (Abraham 1983; Prathibha et al. 2013; Prathibha 2015). As the peak swarming period is short and beetle congregate during swarming, this method can be well practised. It is found that capture of beetles by handpicking is significantly higher than light trapping.

Biological An array of natural enemies was reported on *L. coneophora*. A solitary ecto-larval parasitoid, *Campsomeriella collaris* Fab. (Hymenoptera: Scoliidae), and parasitism by *Prosena* spp. nr *siberita* (Tachinidae: Diptera) as well as a solitary endo-larval parasitoid were reported on *L. coneophora* grub for the first time from organically managed coconut garden. Entomopathogenic bacterium *Serratia entomophila* caused 'amber disease' to *L. coneophora* grubs. White muscardine fungus *Beauveria brongniartii* and green muscardine fungus *Metarhizium* spp. were obtained from infected *L. coneophora*. Epizootic due to caterpillar fungus *Cordyceps* spp. was noticed on third-instar *L. coneophora*. Two species of entomopathogenic nematodes *Steinernema carpocapsae* and *Heterorhabditis indica* are being used in the management of palms against root grubs. In coconut ecosystem, drenching aqua suspension of EPNs *Steinernema carpocapsae* in the interspaces (5–10 cm depth) at 1.5 billion IJ ha^{-1} was found effective. Soil application of EPN should be continued based on the white grub population.

Chemical Control Use of chemical insecticide is a vital component in IPM of root grub, and it is successful when applied in the right stage and season. During the early 1950s, organo chlorine compounds as dust formulations were commonly used for the management of root grubs. Application of 5% chlordane at 28 lb $acre^{-1}$ gave good control of *L. coneophora* grubs in coconut garden (Nirula and Menon 1957; Valsala 1958). Similarly, application of 10% HCH at 56 lb $acre^{-1}$ once a year after south-west monsoon was recommended against white grubs in coconut which was superior to DDT dusting (Nirula 1958). During the 1970s chlorinated hydrocarbons were replaced with organophosphates (OP) and carbamates for use in management of root grubs. Granules such as carbaryl, carbofuran, phorate, quinalphos and thiodemeton at 4, 6 and 8 kg a.i. ha^{-1} evinced 36% reduction in *L. coneophora* grub population (Abraham 1979). In the 1980s, use of emulsifiable concentrate (EC) formulations of chlorinated hydrocarbons, (chlordane, aldrin, dieldrin, heptachlor, etc.) and OP compounds like chlorpyrifos and quinalphos became popular. Drenching the root zone with chlorpyrifos (0.04%) is recommended for the management. In the early 2000s, soil application of neonicotinoid insecticide imidacloprid at 120 g a.i. ha^{-1} or fourth-generation synthetic pyrethroid bifenthrin at 2 kg a.i. ha^{-1} was found effective in the management of the palm white grubs.

A refined IPM strategy was formulated for the effective management of the pest. The various strategies include:

- Handpicking and destruction of adult beetles during peak emergence
- Blanket application of bifenthrin at 2 kg a.i. ha^{-1} (Talstar 10 EC at 20 l ha^{-1} in 500 l of water) when first-instar stage of grubs dominate in the field

- Drenching aqua suspension of EPNs *Steinernema carpocapsae* in the interspaces (5–10 cm depth) at 1.5 billion IJ ha^{-1} during September to October as well as during November to December
- Second round need-based root zone application of chlorpyrifos 20 EC at 7 ml palm^{-1} after 45 days of first round insecticide application
- Repeated ploughing to expose the grubs to predators/digging and removal of grubs during October to December.

12.6 Mammalian Pests

*12.6.1 Rat (***Rattus rattus***)*

12.6.1.1 Distribution

In coconut plantations, eight different species of rodents were observed to coexist (Advani 1984; Advani 1985). Among them, *Rattus rattus wroughtoni* was the most predominant one (45%) followed by the field mouse *Mus booduga* (31%). Other rodents found in association with these mammals were the tree mouse, *Vandeleuria oleracea* (12%); the Western Ghats squirrel, *Funambulus tristriatus* (7%); *R.r. rufescens* (4%); and the Indian gerbil, *Tatera indica* (1%). The burrows of the lesser bandicoot *Bandicota bengalensis* and the larger bandicoot *Bandicota indica* were also found in certain gardens. *R.r. wroughtoni* lived mostly on the tree canopy, whereas *M. booduga* remained on the ground, thus minimizing competition for food and shelter.

Rat (*Rattus rattus*) is the major and threatening mammalian pest of coconut in the island ecosystem both in Lakshadweep and Bay Islands. The damage intensity varied from 14.3% during 1988 to 20.4% during 1990 in the mainland. Advani (1984) has reported that the damage intensity to coconut was more in coconut-cocoa mixed cropping systems (28.5%) than in coconut monocrop system (21%). In Lakshadweep Islands, nut loss as high as 50% was recorded. Detailed studies on population structure; movement pattern; breeding behaviour including breeding season, ovulation rate and litter size; post-natal development; juvenile emergence; and adult persistence were studied by Advani (1985).

Colonies of rats are found on the crowns of the coconut palm feeding on nut. In closely planted coconut gardens, rats jump from tree to tree. All palms are not invaded by the rats perhaps selected palms that yield sweet nut water and pulp are highly preferred. All stages of the nuts were found to be fed by the rats in Minicoy Island making a typical circular hole by gnawing and feed on the inner contents. Gnawing sound of rats is quite audible during dusk, and all islanders are well familiarized to the sound. Under severe conditions, even the emerging spathes are very badly eaten by the rats in the island. Rats are also habituated to make breeding nests using leaflets on the crown of the palms.

12.8.2.4 Alternate Hosts

Hosts of *R. cocophilus* are confined to the family Arecaceae where the nematode is known to infect over 17 species. Most palm species appear to be susceptible to inoculation by red ring nematode. The most economically important species with red ring disease susceptibility are coconut palm, the African oil palm and the date palm.

12.8.2.5 Nematode Management

There are no simple means of controlling red ring disease, and no effective measures are available as yet for control of the nematodes in living palms. Control is based on prevention rather than cure especially involving the destruction of infested palm material as well as trapping and killing of the weevil vectors before they spread the nematodes.

Cultural Since the nematode did not multiply in the insect nor survived for any appreciable time in the dead tree, the only known reservoir of inoculums was the diseased tree in which the vector palm weevils developed. Thus, the elimination of the diseased tree by burning or poisoning, as soon as red ring symptoms appeared, reduced significantly the available source of the pathogen and also controlled the population of the vectors.

Biological The vector weevil is found to be parasitized by several species of Rhabditidae or Heterorhabditidae throughout Latin America. Since the vector insects can be highly parasitized with the above nematodes, selective pressure can be introduced against the vectors. Such measures are being employed in Trinidad with a species of Rhabditidae (Griffith and Koshy 1989).

Chemical The leaf axils of diseased palms should be sprayed with 0.1% Lannate (Methomyl) for the suppression of weevil. Guard baskets made of 2 cm mesh wire are used to protect frequent outbreaks of the disease. These baskets are filled with fresh infected tissue and sprayed with 0.1% Lannate suspension. The palm weevils are attracted to the tissues in the basket. After 2 weeks, the tissues in the basket are burnt. One guard basket is used per 0.4 ha of palms.

12.8.3 Root-Knot Nematode: Meloidogyne incognita

Meloidogyne incognita infests intercrops in coconut system and not on the main crop. In ginger and turmeric, the root-knot nematode causes galling and rotting of roots and underground rhizomes. The nematode also causes severe injuries by way of gall formation in black pepper and vegetable crops.

12.8.3.1 Nematode Management

Control of root-knot nematode infestation in susceptible crops like black pepper, turmeric, ginger, various vegetables and fruit crops in coconut system could be managed by adopting integrated approaches such as crop rotation, selecting less susceptible crops, changing of planting site every year, fallowing and growing of antagonistic crops like marigold in alternate rows or in patches to reduce the nematode buildup in soil (Rajkumar et al. 2016). Regular application of biological agents such as *Trichoderma*, VAM and *Paecilomyces lilacinus* reduced the damaging effect of nematodes (Sosamma et al. 1990).

12.9 Potential Invasive Pests

Alien invasive species (AIS) is a non-native exotic pest which becomes established in natural or seminatural ecosystems or habitat and threatens native biological diversity. The spread of AIS is now recognized as one of the greatest threats to the ecological and economical well-being. Invasions by alien species imbalance native ecosystems and are likely to breed profusely in the absence of natural enemies in the new environment and cause upsets in biodiversity outcompeting native species.

The introduction of new pests into a locality is brought out in various ways such as (1) through a host as the carrier; (2) inert packing materials carrying the quiescent stages of the pest; (3) insect vectors, birds and air currents; and (4) deliberate, illegal introduction as bioweapons. Though the first two modes of distribution are curtailed by quarantine measures, the latter two are beyond the limitations of pest control by exclusion. This creates a need for biosecurity involving integrated approach that encompasses the policy and regulatory frameworks to analyse and manage the risks in the sectors of food safety and other environmental risks (Shetty et al. 2008).

Biosecurity covers the introduction of plant and animal pests and diseases, introduction of genetically modified organisms and their products and introduction and management of invasive alien species and genotypes. As such it is a holistic concept having a direct relevance to the sustainability of agriculture, food safety and protection of the environment including biodiversity. It is in this context that the likely advent of invasive insect pests like coconut leaf beetle (CLB), *Brontispa longissima* Gestro (Chrysomelidae: Coleoptera), and armoured scale insect, *Aspidiotus rigidus* Reyne (Diaspididae: Hemiptera), to India would be devastating and more likely an issue of biosecurity in our country.