POPULATION DYNAMICS AND MANAGEMENT OF COCONUT ROOT GRUB (Leucopholis coneophora Burm.)

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DECLARATION

I, hereby declare that this thesis entitled **"POPULATION DYNAMICS AND MANAGEMENT OF COCONUT ROOT GRUB (*Leucopholis coneophora* Burm.)"** is a *bona fide* record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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ABBREVATIONS

CNSL	Cashew nut shell
et al	Co-workers
EPN	Entomopathogenic nematode
WDG	Wettable dispersible granules
KAU	Kerala Agriculture University
NBAII	National Bureau of Agriculturally Important Insects
LC	liquid concentration
EC	emulsified concentrate
SL	soluble liquid
G	Granules
WG	Wettable granules
DAT	Days after treatment
CD	Critical difference
V	volume
T	treatment
ANOVA	Analysis of variance
cm	centimeter
%	percentage
h	hour
Kg m^{-2}	kilogram per meter square
m	meter
Kg	kilogram
Kg ha^{-1}	kilogram per hectare

gm	gram
@	at the rate of
ml $palm^{-1}$	milliliter per palm
gm kg^{-1}	gram per kilogram
a.i.	active ingredient
a.i. ha^{-1}	active ingredient per hectare
cm^3	cubic centimeter
ppm	parts per million
m^2	metre square
^0C	degree celsius
ml L^{-1}	milliliter per liter
ml	milliliter
mm	millimeter
cm	centimeter
t-test	Student t-test
mm3	cubic millimeter
kg	kilogram

INTRODUCTION

1. INTRODUCTION

Coconut in Kerala plays an important role in its economy and culture. Sandy and sandy loam soils form the majority of the area in the coastal regions of Kerala. Coconut and coconut based homesteads is the major farming system in this region with all the crop combinations. The size of the farm land is small so that intensive cultivation of various crops is undertaken to satisfy the needs.

Root grub, *Leucopholis coneophora* Burmister is an endemic subterranean pest of coconut and other crops in sandy loam soils and prevalent in costal belts of peninsular India. It was first reported as a pest of coconut by Nirula *et al.* (1952).

It tunnels in to the bole and collar region of the seedlings 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 and complete yield loss (Nirula *et al.*, 1952; Abraham and Mohandas, 1988).

Ali and Ganeshaiah (1998) reported that there are 44 genera and 285 species of root grubs in India. In Kerala 12 species were identified which are endemic to sandy loam soils. The pest has annual life cycle and adult emergence coincides with the onset of monsoon (Abraham and Mohandas, 1988).

Presently the grubs are managed by applying soil insecticides belonging to organophosphorus and neonicotinoid groups which gives varying results in farmers' fields (KAU package of practice 2009). Mass capturing and destroying the adults is one of the components in IPM of root grubs. A collective effort by the farmers to collect the emerging beetles from the very first day of the adult activity was suggested by Veeresh, 1983.

In sandy or sandy loam soils with high rainfall, application of pesticides may lead to pollution of groundwater. Moreover, many pesticides which are

recommended for root grub management are banned in Kerala especially in Kasaragod by Govt. of Kerala (G.O. (MS) 310/2010/Agri. Dated 2/12/2010).

Under these circumstances, development of more effective and eco-friendly management measure is imperative. So the present research work has been selected with the following objectives viz, Assessment of population dynamics of coconut root grub (*L. coneophora* Burm.) and developing effective, economically viable and eco-friendly management measures.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

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

2.1 ROOT GRUB AS A PEST OF COCONUT AND OTHER CROPS.

Nirula *et al*. (1952) were the first to report *L. coneophora* as an important pest of coconut from Kerala. 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).

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 causing significant yield loss (Padmanaban and Daniel, 2003).

The nature of damage of *L. coneophora* Burm. was reported by Nirula (1958). The young larvae feed on the tender roots of the coconut palms and grown up grubs found gnawing the well-established roots of the coconut palms and other cultivated crops. Padmanaban and Daniel (2003) reported the feeding habit of *Leucopholis burmestri*. on arecanut palms in Karnataka and Kerala.

Since 1952, a number of authors have reported *L. coneophora* Burm. as the only species that affect coconut from the coastal areas of Kerala (Nirula *et al.*, 1952; Veeresh, 1977; Abraham and Mohandas, 1988).

2.2 POPULATION DYNAMICS OF THE LARVAL STAGES OF ROOT GRUB

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 in the palm basin and X is the number of larvae found up to a depth of 40 cm at a distance of 50-100 cm away from the trunk of the palm.

Field studies were conducted in Eastern Virginia by Jordan *et al,* (2008) to predict spring infestation levels of white grubs in the soil. Sampling involved was removing a standard volume of soil from 20.3 × 20.3 × 15 cm deep soil sample (compact method) from multiple locations in each field and visually inspecting it for white grubs and other soil insect pests.

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

Soil sampling for white grubs in Shimla hills by Chandel *et al.* (2003) revealed high population of all stages of *Brahmina coriacea* (Hope). 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 to April. Third instar grubs caused damage throughout September-October and over wintered in earthen cell up to April. Adult emergence begins in May, maximum being in mid-June.

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 19th 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%) was 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. (Oyafuso *et al.*, 2002).

2.3 POPULATION ASSESSMENT OF ROOT GRUB USING LIGHT TRAPS

Effect of three light sources in light traps (mercury, black and ultra-violet) on insect catch and relationship with weather parameter was studied by Ramamurthy *et al.*, 2010. They reported that Coleopterans dominates the catch followed by Hemiptera, Hymenoptera, Odonata and Diptera. Black light was more efficient on Coleoptera, Orthoptera, Isoptera and Dictyoptera.

At Durgapura, Rajasthan, nine species of white grub adults were caught in the light traps. Maximum numbers of beetles were collected in the month of June followed by July (Annual report of AINP on White grubs and other soil Arthropods, 2011).

Population dynamics of white grubs (Coleoptera: Scarabaeidae) in the rose cultivation of Northern Bangalore was studied by Kumara *et al.* 2009. They reported that scarabaeid adults' emergence began after the 1st rain in April and it was continued up to the last week of September in Bangalore condition. Maximum numbers of adults were recorded between 19.00 and 19.30 hrs and thereafter a little emergence was noticed from each species of Scarabaeids.

Black light trapping was used to monitor adult flight activity of *Euetheo lahymilis* (Coleoptera: Scarabaeidae) in North Carolina (Murillo, 2011).

The efficiency of mercury-vapour lamps, cool white light and ultra-violet light sources to catch scarab beetles in tropical forest was studied by Garcia-lopez

et al. (2011). They recorded no significant difference in the trap performance between the ultra-violet light and mercury-vapour lamps. However these two methods caught significantly more insects, indicating species richness and abundance when compared with cool white light traps.

The ethology of coconut root grub *L. coneophora* Burm. was studied using different light traps and efficiency of light traps also evaluated. There is no significant difference between the capture made in different light traps (Prathibha *et al.,* 2013).

2.4 BIO-ECOLOGY OF ROOT GRUB

Biology of coconut white grub *L. coneophora* Burm. was studied in detail in field cages. Egg period was 23 days, the mean larval duration was 260 and 270 days and pupal duration 25.3 and 25.7 days for male and females respectively (Abraham and Mohandas, 1988).

Mohan and Vidyasagar, 1993 studied the population dynamics of *L. coneophora*. The adult emergence from soil occurs after 4-5 rainy days, irrespective of the amount of rainfall, combined with a sudden fall in soil temperature.

Sufficient soil moisture increases the grub activity in soil but stagnation of water in the field reduces the grub population. High moisture content causes rotting of eggs and death of grubs due to suffocation (Veeresh *et al.,* 1982).

Yadava and Sexena, 1977 reported that sufficient rainfall is required for the emergence of beetles and drought during monsoon causes the death of beetles.

The stagnation of water in the field increases the grub mortality in soil and optimum moisture content increases the grub movement and migration (Yadava, 1991).

Biology and bionomics of palm white grub, *L. burmeisteri* was studied in Karnataka and Kerala, by Padmanaban and Daniel in 1997. Grubs feeding on roots results in stem tapering and yellowing of leaves.

2.5. EVALUATION OF ENTOMOPATHOGENIC NEMATODE, BOTANICALS AND INSECTICIDES AGAINST COCONUT ROOT GRUB

Entomopathogenic nematode

Studies were conducted to test the efficacy of certain Heterorhabditid and Steinernemid nematodes to control Japanese beetle larvae and other white grubs. They were found effective against Japanese beetle larvae and other white grubs (Villani and Wright, 1988).

Sulistyanto *et al*. (1996) reported that liquid cultured Entomopathogenic nematodes *Heterorhabditis megidis* and *Heterorhabditis bactirophora* were found effective against *Aphodius contaminates* and *Phyllopertha horticola* on golf course.

Koppenhofer and Kaya, 1999 reported that the third instar scarab grub *Anomala orientalis* was highly susceptible to *Bacillus thuringiensis*, and interaction between entomopathogenic nematode and *Bacillus thuringiensis* was also near synergistic in the younger and older instars, which also provided acceptable control.

The evaluation of Entomopathogenic nematodes for control of *Phyllophaga* white grub on Christmas tree was studied by Liesch and Williamson in 2010. The nematode *H. bactirophora* provided limited control whereas *S. carpocapseae* did not provide effective control.

The laboratory evaluation of entomopathogenic nematode, *H. indica* (Meerut strain), was conducted against different lepidopteran and coleopteran pests. The susceptibility of insects varied greatly when exposed at different nematode concentrations in filter paper or soil column assay (Prasad *et al.*, 2012).

Shah and Azmi, (2006) tested the virulence of *H. indica* against *Hypera postica*. The rates used were in the range 10-160 infective juveniles and observations were recorded at 24 h intervals. The pest mortality increased with increasing exposure time (24, 48 and 72 h) and increasing nematode rate reduced the time for grub mortality.

Entomopathogenic nematodes, *Heterorhabditis indica* and *Steinernema* sp. were mass produced and the nematode suspension (*H. indica* at 100 IJ/grub) was applied to cardamom roots during evening to control root grub *B. fulvicorne*. The mortality of final instars was observed within a period of 24-48 h (Josephrajkumar *et al*., 2005).

Infectivity of *Heterorhabditis indica* (Rhabditida: Heterorhabditidae) in adults and larvae of white grub (Coleoptera: Melolonthidae) was studied by Sanchez-Saavedra during 2012. Five days after treatment, the mortality of third stage larvae was 46%. For adults, the LT50 was estimated at 48.97 h. No infective juveniles emerged from any of the adults killed by *H. indica.*

Evaluation of certain insecticides, entomopathogenic nematodes and plant products for the management of arecanut root grub, *Leucopholis lepidophora* Blanch was studied by Channakeshavamurthy *et al.* in 2010. The mortality recorded were 55.37% and 60.94% in nematode *Heterorhabditis indica* and fungus *Metarhizum anisopliae* respectively.

From literature it can be discerned that bio-control agent like EPN is not imparting high mortality on root grubs.

Botanical Insecticides

Although both synthetic and natural pesticides are used extensively in the agricultural fields to control crop pests, it is well known that natural pesticides are eco- friendly and are safe to the non-target organisms. The neem tree (*Azadirachta indica*), has long been recognized for its insecticidal properties. Nearly 550 insect pest species are sensitive to Azadirachtin, an active compound extracted from the *A. indica* tree. Pesticides from *A. indica* have become very much popular because of their biodegradability, least persistence and comparatively less toxicity to non-target organisms, economic and easy availability. In India, neem products are effective against various pests of both crop fields as well as stored grains (Debashri and Tamal 2012).

Three oil cakes, neem (*Azadirachta indica*), mahua (*Madhuca longifolia*) and mustard (*Brassica* sp.) were evaluated for their insecticidal properties at 3 and 4 kg/m² in glass jars under laboratory conditions against larvae of *Brahmina coriacea*. Neem cake gave the highest mortality (24-33%) of 1st- and 2nd-instar larvae after 15 days followed by mahua cake (17-19%) (Chandel *et al.*,1996).

The efficacy of biopesticides, viz. neem (*Azadirachta indica*), mahua (*Madhuca indica*), karanj (*Pongamia pinnata*) and jatropa (*Jatropha curcas*) were evaluated on white grubs (*Holotrichia serrata*) in teak nursery. Neem at 5 kg per bed (size 10×1 m), followed by jatropha cake was found to be statistically significant over untreated control, minimizing seedling damage due to white grubs (Meshram and Homkar, 2011).

John *et al*. (2008) evaluated leaf, root and bark extracts of fully grown mature trees of *Artocarpus heterophyllus, Mangifera indica, Ailanthus triphysa, Anacardium occidentale, Tamarindus indica, Tectona grandis, Thespesia populnea, Casuarina equisetifolia, Gliricidia sepium* and *Strychnosnux-vomica* and cashew nut shell liquid (CNSL) for their insecticidal activity against coconut root grub (*Leucopholis coneophora*). Application of the extracts at 10%

concentration gave mortality values on par with the control. However, application of the extracts at 20% concentration generally resulted in significant larval mortality. CNSL also showed potential in controlling the root grub. Phenols and tannins were identified in the extracts; which are believed to be responsible for the insecticidal property of the trees.

The commercially available oil cakes viz. neem, karanj (*Pongamia pinnata*) and mahua (*Madhuca longifolia*) were applied to pots containing 2-year-old arecanut seedlings growing in sterile soil with 10 third instar *Leucopholis burmeisteri* grubs, at rates equivalent to 1000, 1500, 2000 and 2500 kg/ha. Grub mortality was recorded 30 days after treatment. Of the oil cakes, karanj gave the highest mortality (Padmanaban *et al.*, 1997).

Plant products and oil cakes were evaluated against the third-instar larvae of *Leucopholis burmeisteri* in pot experiments under field conditions. Oil cakes of karanj (*Pongamia pinnata*) neem (*Azadirachta indica*) and mahua (*Madhuca indica*) at the rate of 8.5, 19.0, 34.0 g/pot basis were tried against third-instar larvae. Karanj oil cake was found effective over the other plant products and oil cakes after 30 days of application (Padmanaban *et al.*, 1997).

Tests on the effectiveness of eight different insecticidal cakes of vegetable origin against the larvae of *Holotrichia consanguinea* (Blanch.) in the soil were carried out in pots and in the field. The type of cake most effective in keeping the white grub populations low was that made with karanj (*Pongamia glabra*), followed by those made with neem (*Azadirachta indica*) (Nigam, 1977).

Abdullah *et al*, (2006) evaluated botanical products against some major insect pests of sugarcane. The five botanicals includes neem cake, Nimbicidine, neem leaf powder, Bishkatali (*Polygonum hydropiper*) plant powder and tobacco plant powder, against some major pests of sugarcane during the cropping season from November 2002 to December 2003. Results revealed that all botanical products reduced larval (white grub) population. Tobacco plant powder at 100

kg/ha applied in March, April and August showed the highest efficacy of 40.49% in controlling the rootstock borer infestation and reducing 78.36% larval population of white grub.

An experiment was conducted on the growth response of 3rd instar larvae of *Oryctes rhinoceros* infesting the coconut trees. The LC50/96 hours value for the larvae of *Oryctes rhinoceros* were 29.5% for neem cake powder, 24.5% for neem oil and 14.9% for distillery effluent respectively. Entire larval growth was affected with this bio-pesticides and distillery effluent irrespective of its experimental concentrations (Mohan and Padmanaban, 2013).

The effectiveness of natural insecticides on the colorado potato beetle *Leptinotarsa decemlineata*(Say) was evaluated by Mourao *et al*, 2012. The efficacy of 3 bio-insecticides, spinosad, Azadirachtin and *Beauveria bassiana*, against Colorado potato beetle and the effects on defoliation, potato yield, grade and dry matter was studied. The reference insecticide was thiacloprid and water was the control. The efficacy was assessed 2 and 7 days after crop spraying. Spinosad presented the highest efficacy (> 97% mortality) similar to the thiacloprid, while the Azadirachtin and *B. bassiana* were effective against both larval stages only 7 days after crop spraying (65 and 77% mortality).

The literature review of the section shows that karanj cake gave higher control over neem cake. Other plant products were also effective though to a lesser extent.

Chemical insecticides

Evaluation of certain insecticides, entomopathogenic nematodes and plant products for the management of arecanut root grub, *Leucopholis lepidophora* Blanch was studied by Channakeshavamurthy in 2010. Among the different treatments, the imidacloprid 17.8 SL @ 6 ml/palm gave maximum mortality of 96.12 and 95.14 per cent followed by Chlorpyriphos 20 EC @ 12 ml/palm with

93.10 per cent mortality. The next best was carbofuran 3G @ 25 g/palm (90.06 %) followed by phorate 10G @ 25 g/palm (88.69 %).

Different formulations like granular, liquid and liquid seed treatment insecticides were evaluated against white grubs. The granular insecticides found effective are carbofuron 3G @ 750 gm a.i and emamectin benzoate 5G @12.5gm a.i/ha. The liquid formulation insecticides *viz.* fipronil 5SC @ 100 gm a.i/ha and chlorpyriphos 20 EC @ 400 gm a.i/ha and liquid seed treatment chemical Clothianidin 30 WDG @ 2 gm/kg seed was also found to be effective (Annual report of AINP on whitegrubs and other soil Arthropods, 2010 -2011).

The insecticidal activity of Clothianidin, a neonicotinoid insecticide, against *Anomala cuprea* (Hope) was investigated by Iwata and Sakamoto, 2012. Clothianidin showed antifeedent and growth inhibition activities against 3rd instar larvae at 0.10 mg a.i./kg soil. Furthermore, Clothianidin suppressed the crawling movement of 3rd instar larvae at 0.50 mg a.i./kg soil.

Chlorpyrifos has been used against a wide range of soil arthropods on several crops (Kucharek and Edmonton 1991, Giles and Obrycki 1997). Ashok *et al.,* (2012) conducted a field experiment in Jaipur, Rajasthan, during kharif 2009 and 2010 to compare the efficacy of insecticides clothianidian 50 WDG at 240 g/ha, thiamethoxam 25 WG at 600 g/ha, fipronil 5 SC at 3.0 l/ha, fipronil 80 WG at 300 g/ha and bifenthrin 10 EC at 2000 ml/ha with standard controls imidacloprid 17.8 SL at 300 ml/ha, quinalphos 25 EC and chlorpyriphos 20 EC both at 4 l/ha against white grub *H. consanguinea* on groundnut. An untreated control was included. Pooled data of the two years showed that all the insecticide treatments were statistically superior over the untreated control, recording 39.54% mortality and 5.64 q/ha pod yield. The maximum protection (81.53%) over the control was in imidacloprid 17.8 SL followed by clothianidian 50 WDG, which provided 78.60% protection and 8.46% plant damage. Bifenthrin and chlorpyriphos were found least effective.

Field trials were conducted in 2003 and 2004 to assess the effectiveness of Novaluron (Rimon 10EC), a benzoylphenyl urea chitin synthesis inhibitor, for Colorado potato beetle, *Leptinotarsa decemlineata* (Say), management on potato. Foliar applications of Novaluron did not significantly reduce numbers of *L. decemlineata* adults, egg masses, or first instar larvae, but second–fourth instars were greatly suppressed. The results suggest that Novaluron could be a valuable tool in future *L. decemlineata* management programs (Cutler *et al*., 2006).

From the review of the available literature, it is found that studies on root grub *L. coneophora* are meagre.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Coconut root grub is an endemic pest causing severe damage to coconut and other crops, which is prevalent in light sandy and sandy loam soils. The present study on root grub entitled "Population dynamics and management of coconut root grub (*Leucopholis coneophora* Burm.)" was undertaken to assess population dynamics of coconut root grub and to develop effective and eco-friendly management measures. The laboratory studies were carried out at Department of Entomology and field work in the coconut growing blocks of College of Agriculture Padannakkad, Kasaragod situated at 12^0 20' 30'' N latitude, 75^0 04' 15'' E longitude and an altitude of 10 m above mean sea level, which falls in the northern coastal area of Kerala. The materials and methods used in the study are described in this chapter.

3.1 POPULATION ASSESSMENT OF ROOT GRUBS USING LIGHT TRAPS

Assessment of adult population was done by setting different types of light traps during the mass emergence period. The study was conducted during the last week of May to last week of June 2013 and 2014. The three light traps viz. Mercury light trap (250 watt) (plate-1), Ultra-violet light trap with 280-100 nm wavelength (plate-2) and Black light trap with 400-315 nm wavelength(plate-3) were placed at different locations and lights were switched on between 6.00 pm to 6.00 am. The light trap capture was examined daily and number of males and females were recorded. The weather data like soil temperature and rainfall during the period were also recorded.

3.1.1 Separation of sexes of adult root grubs

The adults collected from the different light traps were sexed. Following characters are listed below:

Generally, males are smaller than females. In females, the abdomen is broader posteriorly, which in the male is uniformly narrower both anteriorly and

Plate 1. Mercury light trap

Plate 2. Ultra-violet light trap

Plate 3. Black light trap

posteriorly. The tibial spurs of hind legs in females are broader towards the end, while those of the males are more slender and sharply pointed.

3.2 THE BIOMETRIC OBSERVATIONS OF EGG AND LARVAE OF COCONUT ROOT GRUB

The bio stages of the pest collected from the coconut palm basin were used for biometric observations. The head capsule was measured using the micrometry.

3.3 POPULATION DYNAMICS OF THE LARVAL STAGES OF ROOT GRUB

The number of larvae per unit volume of soil was assessed in the coconut basin at College of Agriculture Padannakkad. The standardized sampling technique by Mohan *et al.* (1997) was used to estimate the root grub population in coconut plantation.

Thirty palms of different age group ranging between 6-20 years were selected randomly.

A pit of 50 cm^3 size was dug in the root zone of the palm at a lateral distance of 100 cm from the bole region and larvae were collected, counted, and used for further studies. The total number of larvae present in the root zone per palm was estimated by the regression equation $Y=3.78 + 1.7938x$, 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 50 cm^3 the regression equation was developed in same soil condition.

3.4 EVALUATION OF ENTOMOPATHOGENIC NEMATODE, BOTANICALS AND INSECTICIDES AGAINST COCONUT ROOT GRUB *Leucopholis coneophora* Burm.

The effect entomopathogenic nematode, botanicals and insecticides against coconut root grubs were studied both in laboratory and field condition with following treatments:

T_1- Entomopathogenic nematode *Heterorhabditis indica* talc formulation 1 billion/acre

T_2- Cashew nut shell liquid 2%

T_3- Neem cake @ 50 kg/cent

T_4- Clothianidin 30 WDG 100g /cent

T_5- Novaluron 10 EC@ 0.05%

T_6- Malathion 50 EC @0.1%

T_7- Chlorpyrifos 20 EC @0.02%.

T_8- Azadirachtin 1500 ppm @ 5ml/L

T_9- Azadirachtin 1500 ppm @ 10ml/L.

T_{10}- Azadirachtin 1500 ppm @ 15ml/L

T_{11}- Absolute control

The entomopathogenic nematode *H. indica* talc formulation was obtained from NBAII, Bangalore. One gram talc formulation contains 20000 infective juveniles. The formulation when tested on larvae of *Corcyra cephalonia*, 100% mortality was obtained and infective juveniles emerged.

The quantity of entomopathogenic nematode talc formulation, neem cake and Clothianidin WDG required for application to the cups, pots and cage were calculated using surface area. The surface area of cup, pot and cage were mentioned under respective headings. Quantity of EPN applied was 2.5gm/pot, 1.2gm/cage and 0.3gm/cup. Quantity of neem cake applied was 25gm/pot, 12.5gm/cage and 3.5gm/cup. Quantity of Clothianidin 0.3gm/pot, 0.15gm/cage and for 0.1g/cup. The required dose of entomopathogenic nematode, botanicals and insecticides were applied as per the treatments, under laboratory cup, field pot and field cage studies

3.4.1 Laboratory cup assay

Disposable plastic cups of size 6.5cm diameter, 8.5cm height and holding 230ml soil (plate-4). The surface area of the cup is 0.0028 m^2. The experiment was laid out in Completely Randomized Design with 11 treatments and five replications. It was repeated three times during September, October and November, 2013. One grub and a piece of potato was kept in the cup and filled with soil and treatments were applied on surface and moisture level was maintained. The suitability of potato as food was tested and confirmed. Experiment was conducted at room temperature with 25 ± 1^0C.

Observations on mortality were recorded on 3rd and 6th day after application of treatments and percent larval mortality was calculated by using the formula:

$$\text{Percent mortality} = \frac{\text{Number of dead larvae}}{\text{Number of larvae released}} \times 100$$

The data were analyzed using ANOVA. The data generated in the experiments conducted in September, October and November were pooled and analysed.

3.4.2. Field study in earthern pots.

Earthern pots of 17 cm diameter and 26 cm height without any hole at the base; with a surface area of 0.02 m^2 holding six litre of soil were used for the experiment. Experiment was laid out in completely randomized design with 11 treatments and five replications. Four grubs were released in each pot and two potatoes were provided as feed. The pots were filled with soil and buried at a depth of 15cm at equal spacing (plate-5). The pots were irrigated with a rose can simulating the rain for maintaining the moisture level near field capacity. The whole experiment was repeated three times during September, October and November 2013.

Observations on mortality were recorded on 6th day after application of treatments and percent larval mortality was calculated by using the formula:

$$\text{Percent mortality} = \frac{\text{Number of dead larvae}}{\text{Number of larvae released}} \times 100$$

The data was analyzed using ANOVA. Pooled analysis of the data generated in experiments performed in September, October and November was done.

3.4.3 Field studies in plastic net cages.

The experiment was conducted in the field using plastic net cages (Plate-6). Cages of 12cm diameter and 20cm height was prepared. Surface area of plastic cage was $0.01m^2$. Suitability of the plastic cages in holding the larvae was tested under field condition and confirmed. Cages were filled with 2.2 litres of soil and two third instar grubs were released. Two pieces of potato were placed in each cage as feed. Then the cage was closed with a lid made out of same material and was hand stitched with nylon twine, and then buried in the field at a depth of 15cm at equal spacing of 15cm (Plate-7). Experiment was laid out in completely randomized design with 11 treatments and five replications. The treatments were applied on the soil surface. When there was no rain, the area was irrigated with a rose can simulating the rain for penetration of the toxicants to inner layer of the soil.

The whole experiment was repeated three times in September, October and November. Observations on mortality were recorded on 6^{th} day after application of treatments by taking the buried cages and opening at sides. The percent larval mortality was calculated by using the formula:

$$\text{Percent mortality} = \frac{\text{Number of dead larvae}}{\text{Number of larvae released}} \times 100$$

The data was analyzed using ANOVA. Pooled analysis of the data generated in the experiments performed in September, October and November was done.

Plate 4. Experiment in plastic cups in the laboratory

Plate 5. Experiment in the pots in the field

Plate-6 Plastic cage used in the field studies

Plate-7 Experiment in plastic cages in field

3.5 REPELLENCY STUDIES USING AZADIRACHTIN AND CASHEW NUT SHELL LIQUID.

The experiments were conducted in plastic trays of 34cm length, 18cm width and 14cm height, holding 20 litres soil. Tray was filled with soil and treatments were applied. The experiment carried out were choice test, no choice test and starvation with no choice test. Experiment was laid out in completely randomized design with 4 treatments and 7 replications.

Treatments were as follows:

T_1- Azadirachtin 1500 ppm @ 5ml/L.

T_2- Azadirachtin 1500 ppm @ 10ml/L.

T_3- Azadirachtin 1500 ppm @ 15ml/L.

T_4- Cashew nut shell liquid 2%.

3.5.1 Choice test

The soil in the tray was divided into equal halves by keeping one rectangular piece of thin iron sheet at the middle. Some space was left below the iron sheet to permit free movement of grubs into the either side of the tray. Two potatoes with a thin coating of edible wax were placed on both sides. Treatments were applied on one side of the tray on the soil surface and five grubs were released in the untreated side.

Comparison between treated and untreated side was done using Paired T-test. Between treatments comparison was done using ANOVA.

3.5.2 No choice test

Trays for no choice test were prepared the same was as described in 3.5.1. In this test, five grubs were released on the treated side and provided with two potatoes. No potatoes were kept in the untreated side.

3.5.3 Starvation with no choice test

Grubs were kept singly in plastic cups without food for three days. Five such grubs were released in the treated side. Initial weight of potatoes was recorded. Final weight was taken after 12 days of treatment. The repellency was calculated using the formula:

$$\text{Percentage protection} = \frac{\text{Final weight of potatoes}}{\text{Initial weight of potatoes}} \times 100$$

3.6 EFFECT OF BOTANICALS ON GERMINATION AND GROWTH PARAMETERS OF COWPEA.

3.6.1 Germination test

Treatments were as follows:

T_1- Azadirachtin1500 ppm 5ml/L

T_2- Azadirachtin1500 ppm 10ml/L

T_3- Azadirachtin1500 ppm 15ml/L

T_4- Cashew nut shell liquid 2%

T_5- Cashew nut shell liquid 4%

T_6- Cashew nut shell liquid 6%

T_7- Untreated control

Experiment was laid out in completely randomized design with 7 treatments and 10 replications. The botanicals were evaluated for their effect on inhibition of germination of cowpea seeds. For this study, petridish of 9 cm diameter was taken. Filter paper was kept inside petridish and 10 seeds were placed equidistantly. The botanicals *viz.* Azadirachtin1500 ppm 5 ml/L, 10 ml/L, 15 ml/L and cashew nut shell liquid 2%, 4% and 6% were poured in the petridish. Separate untreated control was also maintained. Observations recorded were germination percentage, radicle and plumule length on 10 day after the treatment.

Germination percentage was calculated by using formula:

$$\textbf{Germination percentage} = \frac{\textbf{Total number of germinated seeds}}{\textbf{Total number of seed kept}} \times 100$$

3.6.2 Effect of botanicals on growth and development.

Phytotoxic effect of botanicals was evaluated by recording the growth parameters of cowpea. Earthern pots of 18cm diameter and 26cm height was filled with the potting mixture and ten cowpea seeds were sown. One week after germination, four plants per pot were maintained. All agronomic practices as per KAU package of practice recommendations were undertaken. The botanicals used were Azadirachtin1500 ppm @ 5ml/L, 10ml/L, 15ml/L of water and Cashew nut shell liquid 2%, 4% and 6%. A separate untreated control was also maintained. Botanicals were drenched @ 1.5 litres per pot at 15, 30, 45 and 60 days after germination. The observations recorded were plant height, number length, width of leaves, chlorophyll content represented by spad value, and number of pods. Observations were recorded at weekly intervals after treatment. At 15 days interval, one plant each was uprooted from each treatment and weight of shoot, weight of roots, number of root nodules, root nodule length and width were recorded. Root nodule size was calculated by using formula: $V = 4/3\pi r^3$. The data was analyzed using ANOVA.

Plate-8 Repellency studies-choice test

Plate-9 Repellency studies- starvation test

RESULTS

4. RESULTS

Results of different studies on coconut root grub are presented in this chapter.

4.1 POPULATION DYNAMICS OF ROOT GRUBS USING LIGHT TRAPS

In light trap studies, the population of adult *L. coneophora* was assessed using different light traps viz. mercury light trap, ultra-violet light trap and black light trap during 2013 and 2014. The performances of different light traps were evaluated for total adult collection, total female collection and female: male ratio. Data is presented in table 1.

Adult collection during the year 2013

In 2013, among the three light Trap used, the mercury light trap recorded prolonged and highest collection of 380 adults and ultra-violet light trap with 317 adults and black light trap with 112 adults. Out of the total beetles collected, the number of females in the different traps were 58, 38 and 15. The female : male ratio was also highest in mercury light trap (1:6.5). This was followed by black light trap with the ratio of 1:7.4 and least with ultra-violet trap (1:8.3).

Adult collection during the year 2014

During 2014 also there was similar trend in the number of beetles trapped in different types of traps. But there was a reduction in the number of beetles collected in all the three traps. The highest collection of beetles were obtained with mercury light trap followed by ultra-violet light trap and black light trap with 299, 236 and 154 adults respectively. With regard to abundance of sexes mercury light trap collected highest number of adult females of *L. coneophora* (38) with a female: male ratio of 1:7.8 followed by ultra-violet light trap with 27 adults and black light trap with 20 adults. Ultra-violet light trap and black light trap collection showed similar female: male ratio of 1:8.7.

Pooled analysis of light trap data of 2013 and 2014 showed that, mercury light trap performed well with a total collection of 679 adults followed by ultra-violet light trap with 553 adults and black light trap with 286 adults. Mercury light trap collected highest number of female beetles (96) followed by ultra-violet trap (65) and black light trap (35). The female : male ratio was highest in mercury light trap (1:7.1) followed by black light trap (1:8.1) and ultraviolet light trap (1.8.5). The adult emergence started from third week of May in 2013 and 2014 immediately after receipt of summer showers. On the impact of weather parameters on adult emergence, daily maximum and minimum temperature and soil temperature negatively correlated with adult emergence and rainfall correlated positively with adult emergence (Table 2).

4.2 BIOMETRIC OBSERVATIONS OF EGG AND LARVAE OF COCONUT ROOT GRUB

The egg length and width given in Table 3 showed that, egg length ranged from 1.814 mm to 1.960 mm, with a mean of 1.89 mm and egg width ranged from 1.503 mm to 1.573 mm, with a mean of 1.51 mm.

The grub is white fleshy with light brown head, and heavily sclerotized mandibles. The stridulating area is on the more sclerotized part on the inner surface of the mandibles. The maxilla carries the plectrum consisting of peg like teeth which stridulate against the mandibles. Labium is also well chitinized. Antennae have five jointed segments the fourth joints a projection at the posterior end and the fifth joints club like. The head is prominent and downwardly declined.

The head capsule width of different instars of root grubs and mean body weight are presented in Table 4. The mean head capsule width of 1st instar larva was 3.176 mm, 2nd instar larva 4.416 mm and 3rd instar larva 6.642 mm.

Table1. Number of adult *L. coneophora* collected in different light traps during 2013 and 2014

		2013				**2014**				**Grand total**			
Sl.no	**Traps**	**Males**	**Females**	**Total**	**Female: male**	**Males**	**Females**	**Total**	**Female: male**	**Female**	**Male**	**Female: male**	**Grand total**
1	Mercury light trap	322	58	380	1:6.5	262	38	299	1:7.8	96	584	1:7.1	679
2	Ultra-violet light trap	279	38	317	1:8.3	209	27	236	1:8.7	65	488	1:8.5	553
3	Black light trap	97	15	112	1:7.4	154	20	174	1:8.7	35	251	1:8.1	286

Table 2. Correlation of weather parameters with adult emergence

Weather parameters	2013 correlation	2014 correlation
Max temperature	-0.5022	-0.3186
Min temperature	-0.3658	-0.4508
Rainfall	0.51195	0.27900
Soil temperature	-0.4211	-0.3845

Table 3. Length and width of root grub eggs

Egg no	**Length (mm)**	**Width (mm)**
1	1.918	1.561
2	1.848	1.503
3	1.913	1.560
4	1.914	1.560
5	1.803	1.504
6	1.960	1.573
7	1.925	1.563
8	1.916	1.561
9	1.814	1.509
10	1.930	1.531
mean	1.894	1.542
S.E±	0.016	0.008

Table 4. Head capsule width and larval weight of different instars of root grub

larval stage (n=5)	**head capsule width (mm)**	**S.E±**	**larval weight (gm)**	**S.E±**
I instar	3.176	0.02580	0.048	0.0012
II Instar	4.416	0.10097	0.375	0.0079
III Instar	6.642	0.68696	3.772	0.3837

4.3 POPULATION DYNAMICS OF COCONUT ROOT GRUB LARVA.

The larval population was assessed from August 2013 to February 2014 and data was presented in Table 5. The highest larval population of 29.96 per palm was obtained in the month of August 2013, followed by September with 13.70 grubs. From October 2013 to February 2014, the grubs collected were 8.32, 7.7, 7.10, 5.09 and 5.03 in respective months. The mean number of larvae per pit in August was 14.6 with a standard deviation of 8.23, which was reduced to 0.7 per pit in February with a standard deviation of 1.70.

Table 5. Details of sampling done to assess the larval population

Sl.no	Month	Mean number of larvae/pit	Range/pit	Standard deviation	Calculated number of larvae/basin
1	August	14.60	4-21	8.23	29.96
2	September	5.53	3-12	4.17	13.7
3	October	2.53	1-10	2.85	8.32
4	November	2.20	0-10	6.09	7.70
5	December	1.90	0-10	5.95	7.10
6	January	0.73	0-3	1.69	5.09
7	February	0.70	0-3	1.70	5.03

4.4 EVALUATION OF ENTOMOPATHOGENIC NEMATODE, BOTANICALS AND INSECTICIDES AGAINST COCONUT ROOT GRUB *Leucopholis coneophora* Burm.

4.4.1 Laboratory cup assay

The data of laboratory cup studies during September, October and November were analyzed and treatments were found significant at 5% level of significance which is presented in Table 6.

During September the cumulative mortality of root grubs after 6 days of treatment ranged from 0.00 to 100 per cent. Among the treatments, 100 per cent mortality was recorded in the treatments, T_4, T_5, T_6, T_8, T_9 and T_{10} which are statistically on par with T_7 (80.00 percent). Mortality percentage in different treatments during October also followed the same trend as September except T_2-Cashew nut shell liquid 2% which recorded cent per cent mortality. In November also the morality of root grubs had followed similar trend, but T_7 recorded significantly less mortality of 40 per cent, whereas it recorded higher mortality of 80 per cent during September and October. T_1-Entomopathogenic nematode and T_{11} Absolute control had showed no mortality during September, October and November.

The results of laboratory cup studies during the months of September, October and November of 2013 were pooled together to get the most relevant trend. 100 per cent mortality was observed in Novaluron, Clothianidin, Azadirachtin 1500 ppm @ 5ml/L, 10ml/L, 15ml/L and Malathion which are on par with CNSL 2% (80 per cent) followed by Chlorpyrifos (66 per cent) and neem cake.

4.4.2 Field pot studies

The data of field pot studies during September, October and November were analyzed and treatments found significant at 5% level of significance and is presented in Table 7. The cumulative mortality of root grub after 6^{th} day of treatment ranged from zero to 100 per cent. Among the treatments, significantly highest mortality was recorded in the T_6 (100 per cent) which is on par with T_4 (80), T_9 (95) and T_{10} (95). Percentage mortality of root grub during October and November had shown the similar trend of September. But during October, T_2, T_5 and T_8 were also found significantly superior. In all the three months, T_1-Entomopathogenic nematode and T_{11} Absolute control had showed zero mortality.

The results of field pot studies during the months of September, October and November of 2013 were pooled together. Maximum mortality of 98 per cent was observed in treatments with Azadirachtin 10ml/L and 15ml/L followed by Malathion with 97 per cent and Clothianidin with 87 per cent which are significantly higher. Azadirachtin 5ml/L with 62 per cent, CNSL 2% with 58 per cent and neem cake and Novaluron with 45 per cent, Chlorpyrifos with 37 per cent mortality are significantly inferior.

4.4.3 Cage studies

The data of field cage studies during September, October and November showed in Table 8 and treatments found significant at 5% level of significance. The cumulative mortality of root grub after 6 days of treatment ranged from 0.00 to 90 per cent. The highest mortality was recorded in the T_{10} (90 per cent) which is on par with T_4 (70), T_6 (80) and T_9 (80) followed by T_8 (60), T_2 (50), T_5 (50) and T_7 (30) which are on par.

During October, significantly highest mortality of 100 percent was recorded in the treatments, T_4 and T_{10} which are statistically on par with T_2 (90 per cent) and T_6 (80) followed by T_8 (60), T_7 (50) and T_9 (50).

In November 100 per cent mortality was recorded in the treatments T_6 and T_{10} which is on par with T_9 (80 per cent), T_3 (70) and T_8 (70) followed by treatment with Clothianidin. In all three months $T_1$and T_{11} recorded no mortality.

The pooled analysis of the results of field cage studies showed that Azadirachtin15ml/L gave significantly highest mortality (97 per cent) followed by Malathion (87), Clothianidin (73), Azadirachtin 10ml/L (70) and Azadirachtin 5ml/L (63) which are statistically on par. The treatments with CNSL (53 per cent), neem cake and Chlorpyrifos (30) are significantly inferior. The treatments with EPN did not give any mortality and there was no mortality in absolute control.

Table 6. Mean percentage mortality of root grubs under laboratory cup studies in 2013

Treatment no.	Treatment details	Mean Percentage mortality of root grubs on 6th day after treatment			
		September	October	November	Mean
T_1	Entomopathogenic nematode *Heterorhabditis indica*	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)
T_2	Cashew nut shell liquid 2%	60.00 (53.71)	100.00 (88.56)	80.00 (71.14)	80.00 (71.14)
T_3	Neem cake @ 50 kg/40m^2	60.00 (53.71)	40.00 (36.28)	100.00 (88.56)	66.66 (59.52)
T_4	Clothianidin 30 WDG 100g /cent	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)
T_5	Novaluron 10 EC 0.05%	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)
T_6	Malathion 50 EC @0.1%	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)
T_7	Chlorpyrifos 20 EC @0.02%.	80.00 (71.64)	80.00 (71.14)	40.00 (36.28)	66.66 (59.52)
T_8	Azadirachtin 1500 ppm @ 5ml/L	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)
T_9	Azadirachtin 1500 ppm @ 10ml/L	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)
T_{10}	Azadirachtin 1500 ppm @ 15ml/L	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)	100.00 (88.56)
T_{11}	Absolute control	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)
C.D(0.05)		29.946	23.67	23.67	25.765

The figures in parenthesis denote arcsine transformed values

Table 7. Mean percentage mortality of root grubs under field pot studies in 2013

Treatment no.	Treatments details	Mean percentage mortality of root grubs on 6th day after treatment			
		September	October	November	Mean
T_1	Entomopathogenic nematode *Heterorhabditis indica*	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)
T_2	Cashew nut shell liquid 2%	50.00 (47.71)	85.00 (74.14)	40.00 (36.28)	58.333 (52.71)
T_3	Neem cake @ 50 kg/40m^2	15.00 (18.57)	45.00 (42.00)	75.00 (68.14)	45.00 (42.90)
T_4	Clothianidin 30 WDG 100g /cent	80.00 (68.42)	100.00 (88.56)	80.00 (68.42)	86.66 (75.14)
T_5	Novaluron 10 EC 0.05%	25.00 (27.28)	65.00 (54.00)	45.00 (39.28)	45.00 (40.18)
T_6	Malathion 50 EC @0.1%	100.00 (88.56)	100.00 (88.56)	90.00 (79.54)	96.66 (85.66)
T_7	Chlorpyrifos 20 EC @0.02%.	35.00 (33.28)	50.00 (47.71)	25.00 (27.28)	36.66 (36.09)
T_8	Azadirachtin 1500 ppm @ 5ml/L	55.00 (48.00)	65.00 (56.71)	65.00 (56.71)	61.66 (53.80)
T_9	Azadirachtin 1500 ppm @ 10ml/L	95.00 (82.54)	100.00 (88.56)	100.00 (88.56)	98.333 (86.66)
T_{10}	Azadirachtin 1500 ppm @ 15ml/L	95.00 (82.54)	100.00 (88.56)	100.00 (88.56)	98.33 (86.66)
T_{11}	Absolute control	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)
C.D(0.05)		21.87	15.81	22.34	20.01

The figures in parenthesis denote arcsine transformed values

Table 8. Mean percentage mortality of root grubs under field cage studies in 2013

Treatment No.	Treatment details	Mean percentage mortality of root grubs on 6th day after treatment			
		September	October	November	Mean
T_1	Entomopathogenic nematode *Heterorhabditis indica*	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)
T_2	Cashew nut shell liquid 2%	50.00 (45.00)	90.00 (79.54)	20.00 (18.86)	53.33 (47.33)
T_3	Neem cake @ 50 kg/40m^2	10.00 (10.14)	10.00 (10.14)	70.00 (62.42)	30.00 (27.57)
T_4	Clothianidin 30 WDG 100g /cent	70.00 (62.42)	100.00 (88.56)	50.00 (45.00)	73.33 (65.33)
T_5	Novaluron 10 EC 0.05%	50.00 (45.00)	20.00 (18.86)	10.00 (10.14)	26.33 (24.66)
T_6	Malathion 50 EC @0.1%	80.00 (71.14)	80.00 (71.14)	100.00 (88.56)	86.66 (76.94)
T_7	Chlorpyrifos 20 EC @0.02%.	30.00 (27.57)	50.00 (45.00)	10.00 (10.14)	30.00 (27.57)
T_8	Azadirachtin 1500 ppm @ 5ml/L	60.00 (53.71)	60.00 (53.71)	70.00 (62.42)	63.33 (56.61)
T_9	Azadirachtin 1500 ppm @ 10ml/L	80.00 (71.14)	50.00 (45.00)	80.00 (71.14)	70.00 (62.42)
T_{10}	Azadirachtin 1500 ppm @ 15ml/L	90.00 (79.54)	100.00 (88.56)	100.00 (88.56)	96.66 (85.66)
T_{11}	Absolute control	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)	0.00 (1.43)
C.D(0.05)		38.540	24.830	29.475	30.948

The figures in the parenthesis denote arcsine transformed values

4.5 REPELLENCY STUDIES WITH AZADIRACHTIN AND CASHEW NUT SHELL LIQUID

Repellency of root grubs to different botanicals was studied by choice test, no choice test and starvation test. Results are presented in table 9 and 10.

4.5.1 Choice test

In the untreated sides grubs have eaten more quantity of potatoes when compared to the treated sides. In each treatment, the percentage repellency of treated and untreated sides were compared. In the treatment with azadarichtin 1500 ppm @ 5ml/L, the repellency was found non-significant. There were significant differences in T_2, T_3 and T_4. Repellency increased with the increase in concentration of Azadirachtin. CNSL also gave good repellency. In this test, there freedom for the grubs to feed either on the treated or untreated side, so they opted to feed on the untreated side and thus, there was no significant difference in repellency between the treatments on the treated side. Comparison between treated side and untreated side for four treatments, T_1 is non-significant T_2 and T_4 are significantly different and T_3 is found highly significant.

4.5.2 No- choice test

In no-choice test, per cent repellency ranged from 61.59 to 91.65 per cent amongst the treatments. Significantly highest repellency was observed in T_4 (91.65 per cent) followed by T_2 (89.20) and T_3 (80.23). The treatment T_1 showed least repellency of 61.59 per cent.

4.5.3 Starvation test

The per cent repellency of Azadirachtin and CNSL at different doses, ranged from 78.68 to 98.71 percent. The highest repellency was observed in T_3 (98.57%) followed by T_4 (89.60%) and T_2 (85.20%) which were found to be on par and least repellency was observed in T_1 (78.68%).

Table 9. Percentage repellency of root grub towards different botanicals in choice test

Treatments	Untreated side		Treated side		
	Balance weight of potatoes (%)	**quantity of potatoes eaten up (per cent)**	**% Repellency in the treated side**	**Remaining weight of potatoes in percentage**	**T-test value (2.178)**
T_1- Azadirachtin 1500 ppm @ 5ml/L	90.77	9.23	92.76	7.24	NS
T_2- Azadirachtin 1500 ppm @ 10ml/L	74.15	25.86	94.21	5.79	3.03*
T_3- Azadirachtin 1500 ppm @ 15ml/L	74.48	25.52	95.20	4.80	4.17**
T_4- Cashew Nut Shell Liquid 2%	77.06	22.94	91.29	8.71	2.69*
C.D (0.05)	10.07		NS		

* Significant @ 0.05

** Significant @ 0.01

Table 10. Percentage repellency of root grub towards botanicals in no-chioce and starvation tests

Treatment no.	Treatments	No-choice test	Starvation test
		% Repellency (n=14)	% Repellency (n=14)
T_1	Azadirachtin 1500 ppm @ 5ml/L	61.59	78.68
T_2	Azadirachtin 1500 ppm @ 10ml/L	89.20	85.20
T_3	Azadirachtin 1500 ppm @ 15ml/L	80.23	98.71
T_4	Cashew Nut Shell Liquid 2%	91.65	89.54
C.D(0.05		11.48	9.10

4.6 EFFECT OF BOTANICALS ON GERMINATION AND GROWTH PARAMETERS OF COWPEA

4.6.1 Germination test

The results of effect of botanicals on germination of cowpea seeds is presented in Table 11.

The germination percentage varied from 0-97 per cent. The highest germination percentage of 97 was recorded in T_1 followed by T_7 with 95 per cent. The germination of cowpea seeds was completely inhibited in all the concentrations of CNSL 2%. It was observed that inhibition of germination is directly proportional to the increase in concentration of Azadirachtin.

Effect of botanicals on radicle and plumule growth.

The radicle length of germinating cowpea seeds on 10^{th} day after treatment is presented in table 13. The treatment T_1 and T_7 showed significantly highest radicle length of 2.20cm. The complete inhibition of radicle growth was recorded in all CNSL concentrations viz. T_4, T_5 and T_6. With increase in concentration of Azadirachtin, there was proportionate decrease in radicle length.

The plumule length of germinating seeds on 10^{th} day after treatment was noted. The treatment T_7 was statistically significant and recorded the highest plumule length of 14.4cm which is on par with T_1. The treatment T_3 recorded the lowest plumule length of 2.08 cm. There was complete inhibition of plumule growth in CNSL concentrations viz. T_4, T_5 and T_6.

Table 11. Effect of different treatments on germination percentage of cowpea seeds

Treatment no.	Treatment details	Mean germination%
T_1	Azadirachtin1500 ppm 5ml/L	97.00 (85.86)
T_2	Azadirachtin1500 ppm 10ml/L	54.00 (47.50)
T_3	Azadirachtin1500 ppm 15ml/L	23.00 (24.46)
T_4	Cashew nut shell liquid 2%	0.00 (0.90)
T_5	Cashew nut shell liquid 4%	0.00 (0.90)
T_6	Cashew nut shell liquid 6%	0.00 (0.90)
T_7	untreated control	95.00 (83.2)
C.D (0.05)		9.018

The figures in the parenthesis denote arcsine transformed values

Table 12. Effect of different treatments on plumule and radicle length of germinating cowpea seeds.

Treatments	**Treatment details**	**Mean root length of cowpea seeds(cm)**	
		Radicle length (cm)	**Plumule length(cm)**
T_1	Azadirachtin1500 ppm 5ml/L	2.20 (1.63)	14.2 (3.83)
T_2	Azadirachtin1500 ppm 10ml/L	1.35 (1.35)	10.1 (3.24)
T_3	Azadirachtin1500 ppm 15ml/L	1.00 (1.21)	2.08 (1.59)
T_4	Cashew nut shell liquid 2%	0.00 (0.70)	0.00 (0.70)
T_5	Cashew nut shell liquid 4%	0.00 (0.70)	0.00 (0.70)
T_6	Cashew nut shell liquid 6%	0.00 (0.70)	0.00 (0.70)
T_7	untreated control	2.20 (1.63)	14.4 (3.85)
C.D (0.05)	0.05	0.10	0.13

The figures in parenthesis denote $\sqrt{x + 0.5}$ transformed values

4.6.2 Effect on growth parameters of cowpea

Different growth parameters of cowpea at 56 days after treatment were recorded and presented in the table 13.

Plant height

The treatment T_6 recorded the lowest plant height (97cm) and was found to be on par with the T_3, T_4, and T_5. Significantly highest value was recorded in T_1 and T_7 (110cm) followed by T_2 (107.7cm).

Number of leaves

Number of leaves recorded was lowest in T_6 (31.8). The treatment T_1, T_2 and T_7 showed the maximum number of leaves (42) and were statistically significant and is found to be on par with T_3 and T_4.

Leaf length

There was only marginal difference in the leaf length in different treatments and it was ranged between 11 and 12cm. Highest concentrations of Azadirachtin and CNSL significantly reduced the leaf length.

Leaf width

There was no significant difference in the leaf width in the different treatments.

Chlorophyll value (spad value)

The chlorophyll value was lowest in treatment T6 (41.98) which was found to be statistically significant. Treatment T7 showed the highest chlorophyll content with 52.92 and is on par with T1 and T2 showing 50.72 and 50.10 chlorophyll value respectively.

Table 13. Effect of different treatments on growth parameters of cowpea

Treatment no.	**Treatment details**	**Plant height (cm) (n=10)**	**Number of leaves(n=10)**	**Leaf length(cm) (n=10)**	**Leaf width(cm) (n=10)**	**Chlorophyll content(spad) (n=10)**
T_1	Azadirachtin1500 ppm 5ml/L	110.0	42.0	12.0	9.0	50.72
T_2	Azadirachtin1500 ppm 10ml/L	107.7	42.0	12.0	9.0	50.10
T_3	Azadirachtin1500 ppm 15ml/L	101.0	35.0	11.0	8.7	47.10
T_4	Cashew nut shell liquid 2%	99.80	33.8	12.0	9.0	42.54
T_5	Cashew nut shell liquid 4%	98.90	32.5	12.0	8.9	42.44
T_6	Cashew nut shell liquid 6%	97.00	31.8	11.2	8.0	41.98
T_7	untreated control	110.0	42.0	12.1	8.1	50.92
C.D@ 0.05 %		2.921	1.27	0.19	N.S	1.08

Number of pods

There was no significant difference in the mean number pods in between treatments after 30 days of treatment application, but after 45 and 60 days after treatment, T_7 (control) yielded highest number of pods 10.60 and 12.4 respectively which is on par with the treatment T_1 and T_2. The lowest number of pods observed in the treatment T_6 was 6.2 and 8.8 at 45 and 60 days after treatment respectively (Table 14).

Root fresh weight

The mean fresh weight of root at 15 days after treatment was recorded. T_6 with CNSL 6% recorded the lowest value of 0.6gm, which is statistically on par with T_3-Azadirachtin1500 ppm 15ml/L (0.75gm). The highest root weight was observed in the treatment T_7 –untreated control (2.80gm) followed by T_1 (2.20gm). At 30 days after treatment, the lowest fresh root weight was recorded in T_6 (0.83gm). Highest root weight was recorded in the treatment T_7 (4gm) followed by T_1 (3.3gm). Root weight at 45 and 60 days after treatment has followed the same trend, the treatment T_6 and T_3 yielded the least and highest in T_6 and T_3 (Table 15).

Shoot weight

The effect of botanicals on the mean shoot weight at 15, 30, and 45 days after treatment is presented in Table 14. The significantly least value was observed in T_6- CNSL 6% (6.83gm) and T_3-Azadirachtin1500 ppm 15ml/L (10.30gm). Highest shoot weight was noted in the treatment T_7 (26.6gm) followed by T_1 (23.3gm) which is statistically on par with T_2 (22.66gm). At 30 days after also, the treatment T_6 recorded the least and T_7 recorded the highest shoot weight followed by T_1- Azadirachtin1500 ppm 5ml/L 1500 ppm 5ml/L (25.3gm). Shoot weight at 45 and 60 days after treatment has followed the same trend. The treatments T_7 and T_1 yielded the highest shoot weight and lowest was noticed in T_3 and T_6. It was observed that the increase in the concentrations of CNSL and

Table14. Mean number of cowpea pods under different treatments

Treatment no.	Treatments	Mean number of pods (cumulative)		
		30DAT	45 DAT	60 DAT
T_1	Azadirachtin1500 ppm 5ml/L	3.90	10.00	12.30
T_2	Azadirachtin1500 ppm 10ml/L	4.60	8.00	12.20
T_3	Azadirachtin1500 ppm 15ml/L	3.80	6.50	11.20
T_4	Cashew nut shell liquid 2%	4.60	6.80	10.20
T_5	Cashew nut shell liquid 4%	3.30	6.90	10.10
T_6	Cashew nut shell liquid 6%	3.10	6.20	8.80
T_7	untreated control	4.10	10.60	12.40
C.D@ 0.05		NS	3.32	2.01

DAT- Days After Treatment

Table 15. Mean root weight of cowpea under different treatments

Treatment no.	Treatments	Mean root weight of cowpea (gm)			
		15 DAT	30 DAT	45 DAT	60 DAT
T_1	Azadirachtin1500 ppm 5ml/L	2.20	3.30	7.16	10.00
T_2	Azadirachtin1500 ppm 10ml/L	1.40	1.77	2.18	9.30
T_3	Azadirachtin1500 ppm 15ml/L	0.75	1.30	2.04	8.00
T_4	Cashew nut shell liquid 2%	1.20	1.46	5.30	8.00
T_5	Cashew nut shell liquid 4%	1.00	1.64	2.26	7.00
T_6	Cashew nut shell liquid 6%	0.60	0.83	2.16	6.00
T_7	untreated control	2.80	4.00	6.93	11.0
C.D@ 0.05		0.28	0.19	0.53	0.38

DAT- Days After Treatment

Azadirachtin there was decrease in the mean shoot weight, which is presented in table 16.

Mean number of root nodules

Concentrations botanicals adversely affected the root nodule formation. With increase in concentrations of CNSL, the mean number of root nodules developed at 15, 30, 45 and 60 days after treatment showed decrease in nodule numbers with lowest in 6% concentration and highest in 2 % concentration.

The mean number of root nodules was found to be higher in the untreated control (T_7) at 15, 30, 45 and 60 days after treatment which is statistically significant followed by T_1 with second highest number of root nodules at 15, 30, 45 and 60 days after treatment. Azadirachtin 1500 ppm 5ml/L gave only less number of root nodules, which is presented in the table 17.

Mean root nodule size

Root nodules size at 15 days after treatment varied from 0.18mm^3 to 1.94mm^3. Least value was recorded in T_6 (0.18mm^3) followed by T_3 (0.48 mm^3) which is statistically on par with T_5 (0.49mm^3). The significantly highest root nodule size was recorded in T_7 (1.94mm^3) followed by T_1 (1.48) which is on par with T_2 (1.29mm^3).

At 30 days after treatment, least root nodule size was recorded in T_6 (0.45mm^3) which is on par with T_5 (0.54mm^3), T_4 (0.80mm^3) and T_3 (0.92mm^3). The significantly highest value observed in T_7 (2.22mm^3) which is on par with T_1 (1.80mm^3).

Root nodule size at 45 days after treatment varied significantly. The least value was recorded in T_6 (0.90mm^3) which is on par with T_5 (1.03mm^3) and T_4 (1.15mm^3). The highest value recorded in T_7 (2.41mm^3) which is on par with T_1 (2.40mm^3), T_2 (1.87) and T_3 (1.59mm^3).

At 60 days after treatment, the size of root nodules was increased significantly. The least value recorded in T_6 (1.00mm^3) which is on par with T_5 (2.64mm^3). The highest root nodule size was recorded in T_7 (6.77mm^3) followed by T_1 (4.53mm^3) which is on par with T_2 (2.99mm^3) and T_3 (2.76mm^3). Data is presented in the table 18.

Table 16. Mean shoot weight of cowpea under different treatments

Treatment no.	Treatments	Mean shoot weight of cowpea (gm)			
		15 DAT	30 DAT	45 DAT	60 DAT
T_1	Azadirachtin1500 ppm 5ml/L	23.5	25.50	31.66	130.0
T_2	Azadirachtin1500 ppm 10ml/L	22.66	22.00	30.83	100.0
T_3	Azadirachtin1500 ppm 15ml/L	10.33	14.33	26.16	74.66
T_4	Cashew nut shell liquid 2%	16.66	20.00	30.66	84.66
T_5	Cashew nut shell liquid 4%	13.16	18.33	28.50	59.33
T_6	Cashew nut shell liquid 6%	6.83	7.53	14.16	40.33
T_7	untreated control	26.66	31.66	32.33	133.33
C.D@ 0.05		0.876	1.75	0.99	2.261

DAT- Days After Treatment

Table 17. Mean number of root nodule under different treatments

Treatment no.	Treatments	Mean number of root nodules			
		15 DAT	30 DAT	45DAT	60 DAT
T_1	Azadirachtin1500 ppm 5ml/L	23.00	23.33	25.00	16.33
T_2	Azadirachtin1500 ppm 10ml/L	5.66	5.66	6.00	14.33
T_3	Azadirachtin1500 ppm 15ml/L	1.66	3.00	2.00	10.00
T_4	Cashew nut shell liquid 2%	15.66	17.00	13.66	20.33
T_5	Cashew nut shell liquid 4%	9.66	7.00	8.00	3.33
T_6	Cashew nut shell liquid 6%	1.00	2.00	6.00	1.33
T_7	untreated control	30.66	30.00	25.33	23.66
C.D @ 0.05		2.53	2.26	0.85	1.14

DAT- Days After Treatment

Table 18. Mean root nodule size of cowpea roots under different treatments

Treatments no.	Treatments	Mean root nodule size (mm^3)			
		15 DAT	30 DAT	45.DAT	60 DAT
T_1	Azadirachtin1500 ppm 5ml/L	1.48	1.80	2.40	4.53
T_2	Azadirachtin1500 ppm 10ml/L	1.29	1.53	1.87	2.95
T_3	Azadirachtin1500 ppm 15ml/L	0.48	0.92	1.59	2.76
T_4	Cashew nut shell liquid 2%	0.55	0.80	1.15	2.64
T_5	Cashew nut shell liquid 4%	0.49	0.54	1.03	2.46
T_6	Cashew nut shell liquid 6%	0.18	0.45	0.90	1.00
T_7	untreated control	1.94	2.22	2.41	6.77
C.D @0.05		0.22	0.72	0.85	1.75

DAT- Days After Treatment

DISCUSSION

5. DISCUSSION

5.1 POPULATION DYNAMICS OF ROOT GRUBS USING LIGHT TRAPS

Studies conducted revealed that the adult emergence started from last week of May in 2013 and 2014 on receipt of summer showers. The adult emergence during 2013 and 2014 was correlated with the weather data viz. soil temperature, rain fall and daily maximum and minimum temperature. No emergence was noticed during initial three weeks of May as there was no rainfall and soil temperature was quite high (36.28± 2.5ºC). This is in line with the results by Yadava and Saxena (1977), who reported that sufficient rain was required for the emergence of melolonthid cock chafer, *Holotrichia serrata*. During 2013 and 2014, rainfall positively correlated with adult emergence because rainfall reduced the soil temperature. Maximum temperature and minimum temperature were negatively correlated with the adult emergence, which shows that decrease in ambient temperature resulted in increased adult emergence. Soil temperature also negatively correlated with adult emergence. Soil temperature is the most important weather parameter which has got maximum bearing on adult emergence irrespective of the amount of rainfall was reported by Mohan and Vidyasagar, 1993.

Efficiency of different light traps

Three light traps viz. mercury, ultra-violet and black light traps were evaluated for their efficiency in collecting the adult root grub *L. coneophora.* The study was conducted during 2013 and 2014. The results revealed that mercury light recorded the prolonged collection upto last week of June. Mercury light trap recorded highest collection of 679 adults followed by U.V light trap and least in black light trap. Ramamurthy *et al.* (2010) reported that mercury light trap was more attractive for the majority of the insects and black light was more attractive to Coleoptera, Orthoptera and Isoptera. Mercury and black light sources shown similar attractiveness for coleopterans. In a study by Garcia-Lopez *et al.* (2011)

on the efficiency of different light sources, mercury-vapour lamps, cool white light and ultra-violet sources also attracted Dynastinae, Melolonthinae and Rutilinae scarab beetles. There was no significant difference in the performance between ultra-violet and mercury light traps. The mercury light trap recorded highest collection of 96 females followed by ultra-violet with 65 females and least in black light trap with 35 females. The overall sex ratio recorded was 1:7.7. In a study by Prathibha *et al.* (2013) the sex ratio observed was 1:5.37. See Table 1 and 2 Figures 1, 2, 3 and 4.

5.2 BIOMETRY OBSERVATIONS OF EGG AND LARVA OF COCONUT ROOT GRUB

The biometric observations of root grub viz. the egg length and width: head capsule length and width of different instars are presented in Table 3, 4 and Figure 5. The results are in agreement with the findings of Abraham and Mohandas (1988). Since the ratio of the head capsule between successive instars mean is 1.4, it shows that przibram's law is observed and the insect have only three larval instars.

5.3 POPULATION DYNAMICS OF ROOT GRUB LARVA

Sampling was done to assess the larval population of coconut root grub. A technique standardized by Mohan *et al.* (1997) was adopted to assess the larval population. Sampling was done from August, 2013 to February 2014. The highest number of 30 grubs per palm basin was recorded in the month of August followed by September. Thereafter gradual decrease in the population of white grub has been noticed. There was six fold decrease in the larval population by February. Many biotic and abiotic factors act on the larval population such as competition, food availability and natural enemies etc. resulting in reduction in larval population. Moreover, during dry time when sand is hot, the grubs move deeper into the soil. See Table 5 and Figure 6.

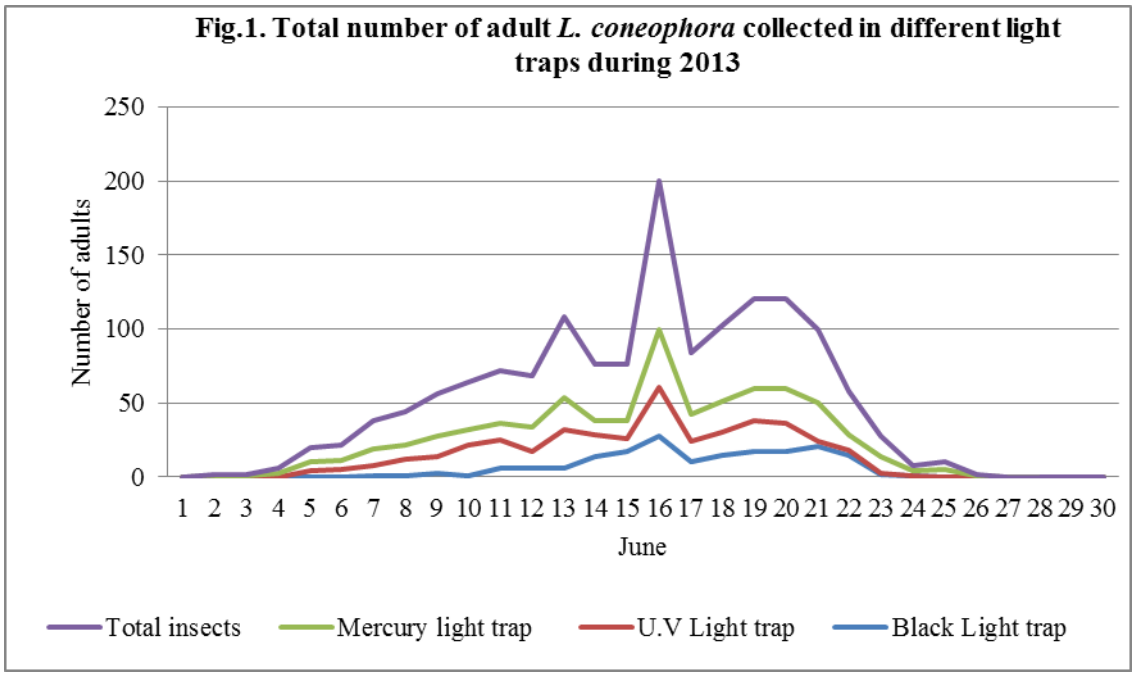


Fig.1. Total number of adult L. coneophora collected in different light traps during 2013
Number of adults
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
June
Total insects
Mercury light trap
U.V Light trap
Black Light trap

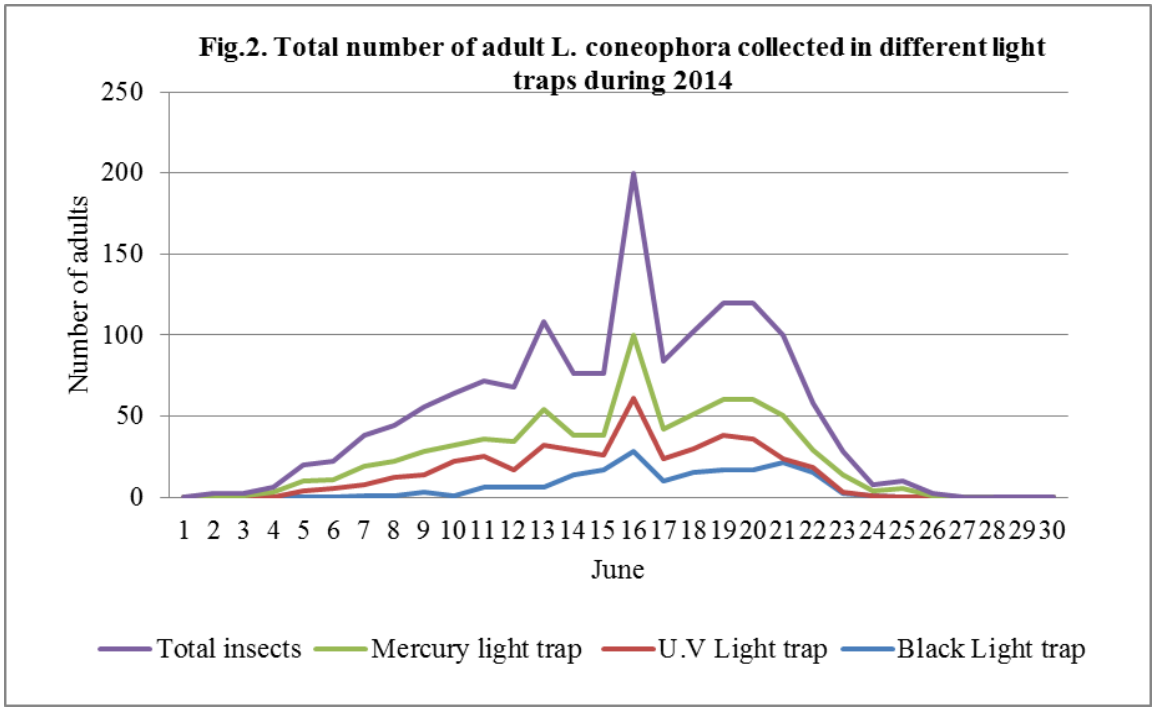


Fig.2. Total number of adult L. coneophora collected in different light traps during 2014
Number of adults
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
June
Total insects
Mercury light trap
U.V Light trap
Black Light trap

Fig.3. Adult females of *L. coneophora* collected in different light traps during 2013 and 2014

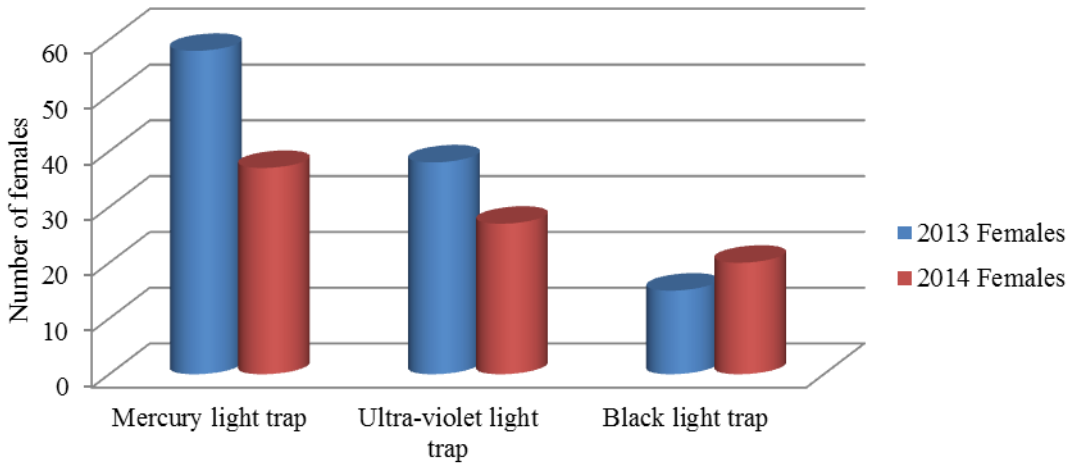
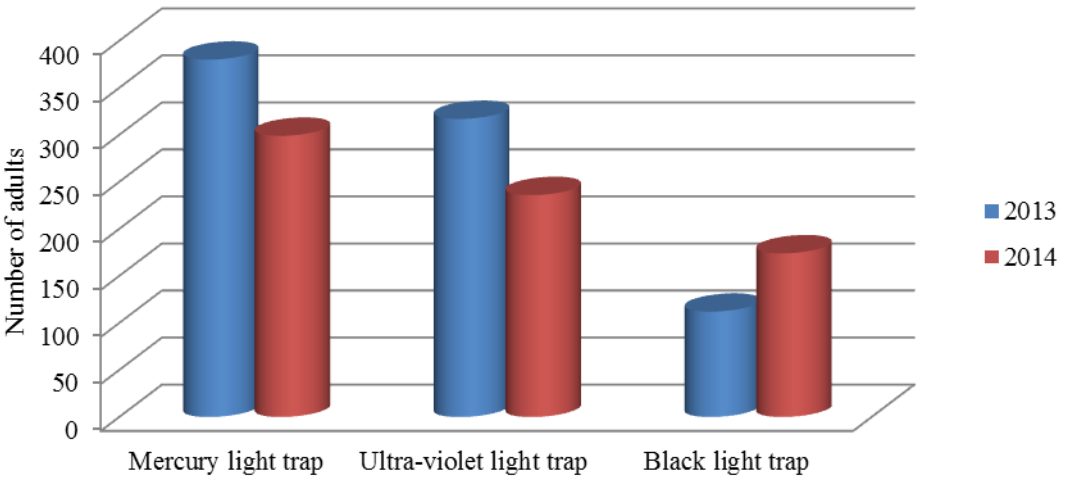


Fig.4.Total number of adult *L.coneophora* collected in different light traps during 2013 and 2014



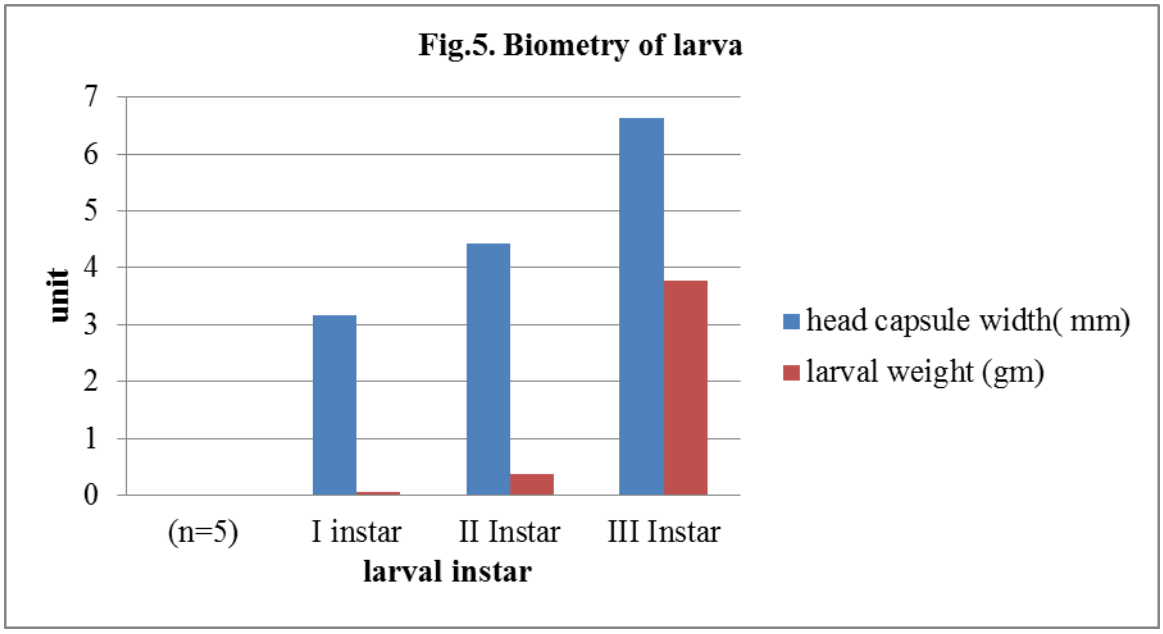


Fig.5. Biometry of larva
7
6
5
4
3
2
1
0
unit
(n=5)
I instar
II Instar
III Instar
larval instar
head capsule width(mm)
larval weight (gm)

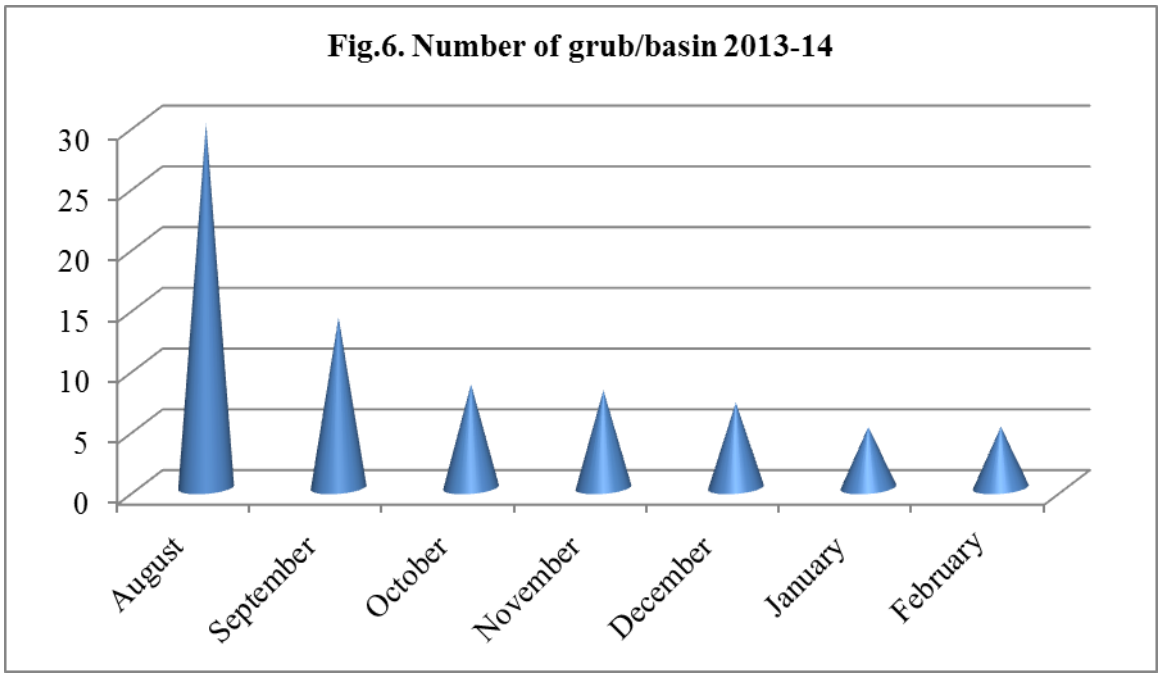


Fig.6. Number of grub/basin 2013-14
30
25
20
15
10
5
0
August
September
October
November
December
January
February

5.4 EVALUATION OF ENTOMOPATHOGENIC NEMATODE, BOTANICALS AND INSECTICIDES AGAINST COCONUT ROOT GRUB *Leucopholis coneophora* Burm.

Evaluation of entomopathogenic nematodes, botanicals and insecticides against coconut root grub was done in the laboratory, field pot and cage conditions. In plastic cups, on sixth day after treatment, all the treatments except EPN and control caused a mortality ranging from 66-100 per cent. This is due to the fact that in plastic cups larvae were kept in a captive condition and when chemical was applied in the cups, there was better contact with toxicant resulting in higher mortality. In pot experiment also, majority of the treatments gave 36-98 per cent mortality of grubs. Here also grubs were placed in a limited captive condition resulting in better contact with the toxicant. But in cage experiments, 30-96 per cent mortality of root grub was observed. In field pots, three treatments gave more than 90 per cent mortality where as in field cage studies only one treatment gave more than 90% mortality. This is due to the fact that the cages were buried at 15cm depth and toxicant was applied on the surface. This is a near simulation of the actual field situation. Among the treatments in cage studies, only Azadirachtin 1500 ppm 15ml/L gave more than 90 per cent mortality. Malathion 50 EC gave 86 per cent followed by Azadirachtin 1500 ppm 10ml/L (70%) and Clothianidin 30 WDG (73%). Cashew Nut Shell Liquid 2% gave 53.33 per cent mortality and neem cake gave 30 per cent mortality. The details are in Tables 6, 7, 8 and Figures 7, 8 and 9.

Entomopathogenic Nematode, *Heterorhabditis indica*

In the treatments with entomopathogenic nematode *Heterorhabditis indica* there was no mortality in any of the experiments conducted under lab and field conditions. In the experiment conducted by Liesch and Williamson in 2010 to control the white grub (*Phyllophaga*) on Christmas tree, EPN provided limited control. In another study using *H. indica* by Sanchez-Saavedra during 2012, 46

per cent mortality was recorded and no infective juveniles emerged from any of the adults killed by *H. indica.*

Cashew Nut Shell Liquid 2%

Cashew Nut Shell Liquid 2% tried on 3rd instar larvae of coconut root grub was effective in giving more than 50 per cent mortality. The mean percentage mortality obtained from laboratory cup, field pot and field cage studies were 80, 58.33 and 53.33 percent respectively. Our results are in agreement with studies conducted by John *et al.* (2008) who reported 100 per cent mortality in field pots. In the present study, less mortality may be due to the use of third instar root grubs for the experiment.

Neem cake

Neem cake, the mean percentage mortality of 66.66% in cup studies, 45% in pot studies and 30% in field cage studies were observed. The efficacy of neem cake on *H serrata* was proved by Nigma (1977), neem cake was found effective. Present study showed 30% mortality of root grubs in field cages, which is in conformity with Chandel *et al.* (1996), who reported mortality of 24-33% on different instars of root grub larvae *Brahmina coriacea* by neem cake in glass jar under laboratory condition. The results of Meshram and Homkar (2011) had shown similar trend, where neem cake 5kg per bed in teak nursery gave effective control of root grub *H. serrata*.

Chemical insecticides

In the treatment with Clothianidin 30 WDG, the mean percentage mortality of 100% in cup studies, 86.66% in pot studies and 73.33% in field cage studies were observed. A study on potato variety Kufri Jyothi in Palampur showed that the treatment with Clothianidin resulted in less tuber damage due to root grub when compared with control (Annual Report of AINP on white grubs and other soil arthropods 2010-2011). The two year pooled data of 2009 and 2010 study

revealed that Clothianidin (dantotsu®) 30WDG at 2 g/kg of soyabean seeds provided maximum protection against white grub (Annual Report of 2010-2011).

In the treatment with Novaluron 10 EC, the mean percentage mortality of 100% in cup studies, 45% in pot studies and 26.33% in field cage studies were observed. Novaluron 10 EC has inflicted less mortality of 26.33% when compared with the other insecticides. Cutler *et.al* (2006) reported that Novaluron did not significantly reduce the number of Colorado potato beetle adults, egg mass, first instar larvae but second – forth instar larvae were greatly suppressed. Reference on application of Novaluron in the soil against soil borne pests was not available.

In the treatment with Malathion 50 EC, the mean percentage mortality of 100% in cup studies, 96% in pot studies and 86% in field cage studies were observed. Malathion 50 EC has shown significantly and consistently higher mortality percentage compared with other insecticides. Reference on soil application of Malathion against root grub larvae was not available. This result is promising because Malathion with reduced toxicity can replace other more toxic and persistent insecticides in root grub management.

Chlorpyrifos has given a mortality of 66% in cup studies, but pot studies (36%) and cage studies (30%) show a low mortality. Study by Prabhu *et al.* (2011) found that chlorpyriphos 20 EC at the rate of 6 ml per palm was highly effective treatment with 77.36 per cent mortality of grubs. Study by Channakeshavamurthy (2010) found that chlorpyriphos 20EC@ 12ml/palm was highly effective treatment with 93.10 per cent mortality of root grubs. In the present study, lower mortality may be due to the use of sturdier third instar larve used in the experiments.

All the three concentrations Azadirachtin 1500 ppm performed in laboratory cup studies, but in pot studies, Azadirachtin 1500 ppm 10ml/L and 15ml/L performed well with 98.33% mortality. Field cage studies showed that Azadirachtin 1500 ppm 10ml/L and Azadirachtin 1500 ppm 15ml/L performed

well with 70% and 96% mortality respectively but statistically on par. High per cent mortality in treatments with Azadirachtin is also promising because it can replace more toxic chemical insecticides.

5.5 REPELLENCY STUDIES USING AZADIRACHTIN AND CASHEW NUT SHELL LIQUID

The repellency of Azadirachtin and CNSL on coconut root grub was studied by choice test, no-choice test and starvation test. In choice test the grubs were given a choice of moving to either treated or untreated side and eat the potatoes buried in the soil. The larvae ate more quantity of potatoes in the untreated side. This shows that the larvae were repelled by Azadirachtin as well as CNSL. The potatoes buried in soil which was treated with Azadirachtin 15ml/L were eaten by grubs to the extent of 4.71% only, which shows a repellency of 95.29 per cent. The percentage repellency found in other treatments was 92.76%, 94.21% and 91.29% for Azadirachtin 5ml/L, Azadirachtin 10ml/L and CNSL 2% respectively. But all the treatments are statistically on par. In the no choice test, the potatoes were buried only in the treated side and grubs had no choice but to move to the treated side to feed on the potatoes. Here CNSL 2% gave significantly higher repellency of 91.65% followed by Azadirachtin 10ml/L (89.20%). In starvation test, Azadirachtin 15ml/L gave 98.71% repellency, which was significantly highest followed by CNSL 2% with 89.54% repellency. With increase the concentration of Azadirachtin, the percentage repellency increased. References on previous studies of this nature are not available to make comparative analysis. The data is presented in Table 9, 10 and in Figures 10, and 11.

5.6 EFFECT OF BOTONICALS GERMINATION AND GROWTH PARAMETERS OF COWPEA.

5.6.1 Germination test

The phytotoxic effect of Azadirachtin 1500 ppm and CNSL at different concentrations on germination percentage and radicle and plumule growth of cowpea seeds was studied. Germination percentage was found unaffected in the treatment Azadirachtin 1500 ppm 5ml/L. With increase in the concentration of Azadirachtin, there was proportionate decrease in the germination percentage. 77% reduction in germination percentage of cowpea seeds was noticed in Azadirachtin 15ml/L followed by Azadirachtin 10ml/L with 46% reduction. The complete inhibition of germination of cowpea seeds was observed in the treatments with CNSL at all concentrations used. Radicle and plumule length show no inhibition in Azadirachtin 1500 ppm 5ml/L. But when the concentration of Azadirachtin increased, the growth of plumule and radicle has decreased. The data is presented in Table 11, and in Figures 12 and 13.

5.7 Effect on growth parameters.

Cowpea crop was grown in pots and treated with botanicals four times at 15 days interval. The biometric observations like plant height, number of leaves, leaf length and leaf width, chlorophyll value (spad value) and number of pods were noted at definite time interval. The result shows that the treatment with Azadirachtin 1500 ppm 5ml/L and CNSL 2% had inhibited the crop only to a less extent, but with other treatments, there was significant decrease in the growth parameters. The data is presented in Table 13 and in Figure 14.

The destructive analysis of cowpea plant at definite intervals was done. Observations viz. fresh root weight, fresh shoot weight, number of root nodules and size of root nodules at different interval of time were noted. The results indicated that the treatments with Azadirachtin 1500 ppm 5ml/L and CNSL 2% had a slight adverse effect on fresh root weight, fresh shoot weight, number of root nodules and size of root nodules of cowpea plant. However, in other treatments, significant decrease in growth was noticed with the increase in concentrations of Azadirachtin and CNSL. The data is presented in Tables 15, 16 and 17, 18 and in Figures 15, 16, 17 and 18.

Fig.7 Mean percentage mortality of root grubs in laboratory cups during 2013

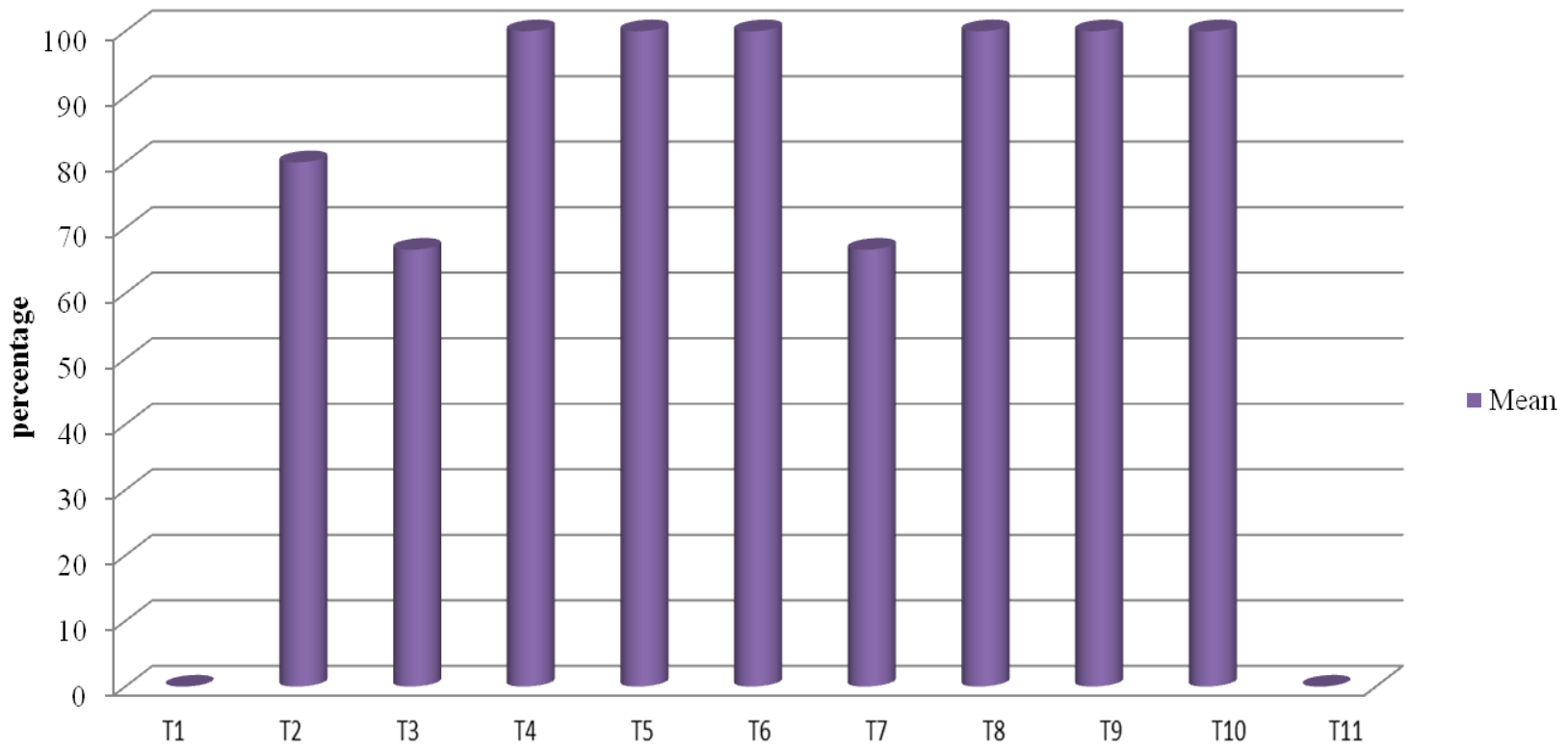


Fig.8. Mean percentage mortality of root grubs in field pot studies during 2013 (pooled data)

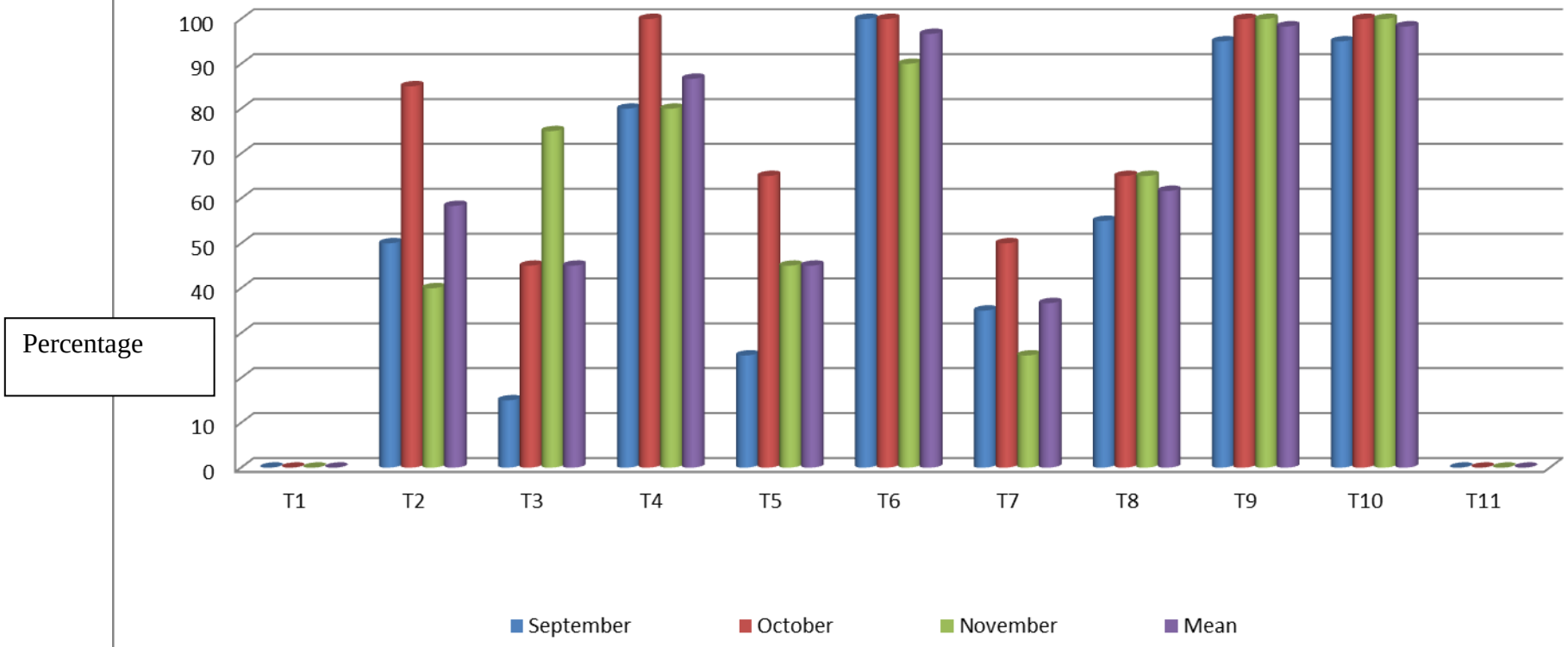


Fig.9. Mean percentage mortality of root grubs in field cage studies during 2013 (pooled data)

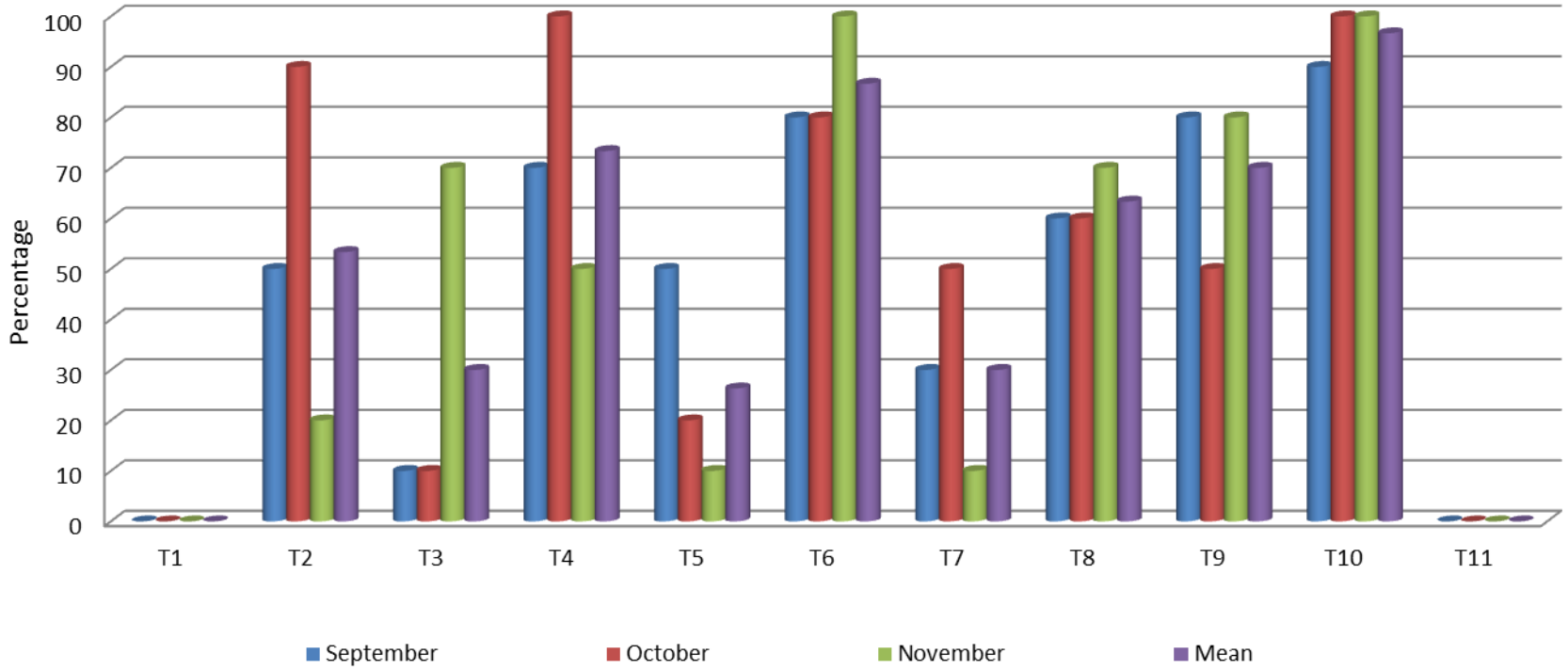


Fig. 10. Percentage repellancy to root grub in no-choice test

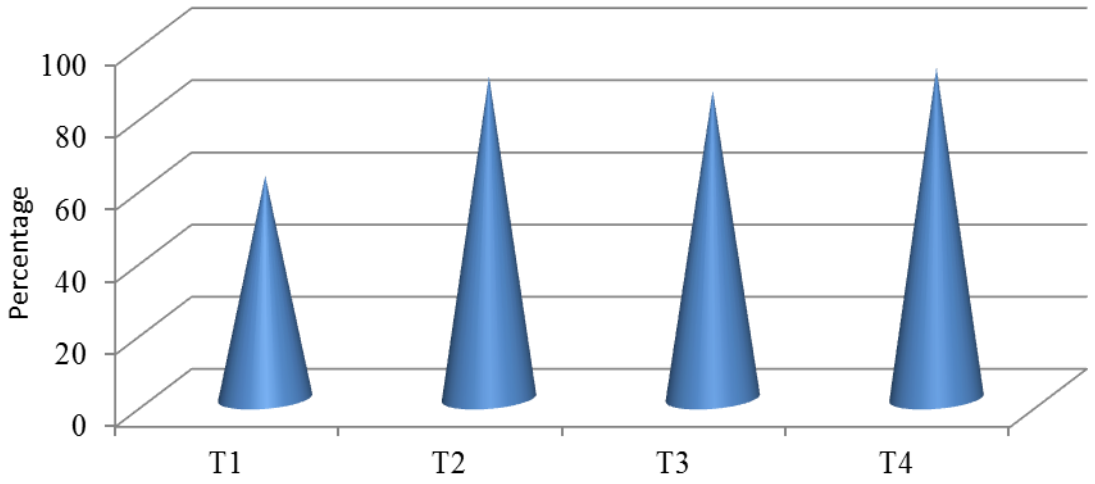


Fig. 11. Percentage repellancy to root grub in starvation test

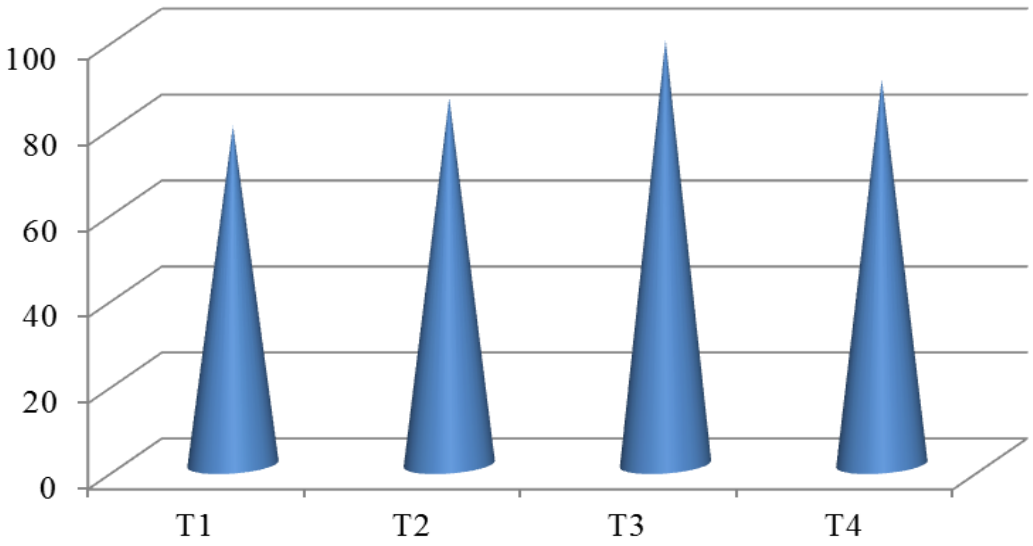


Fig. 12. Effect of different treatments on germination percentage of cow pea

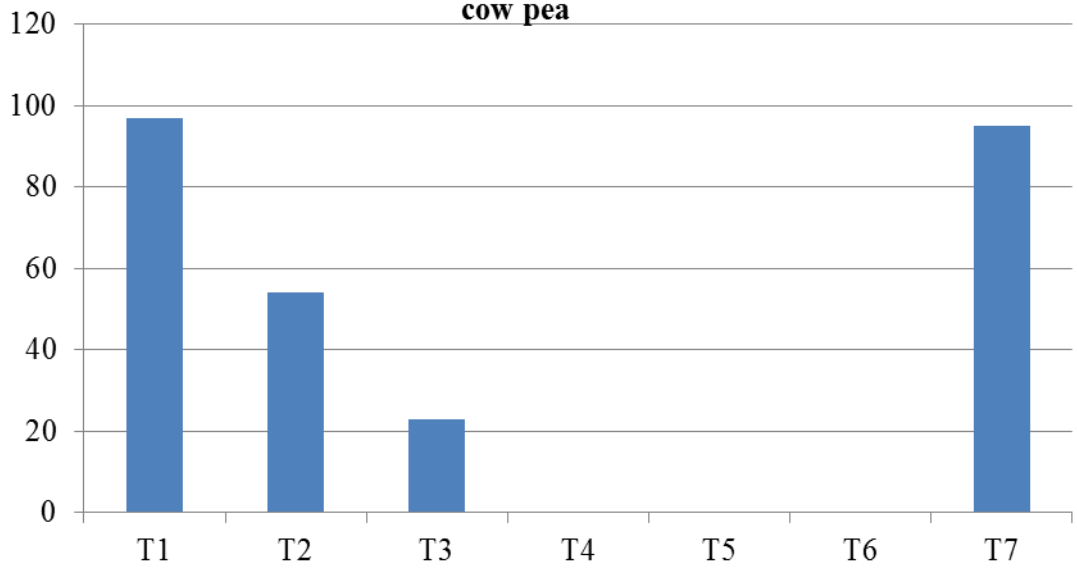


Fig. 13. Effect of different treatments on plumule and radicle length of cowpea (cm)

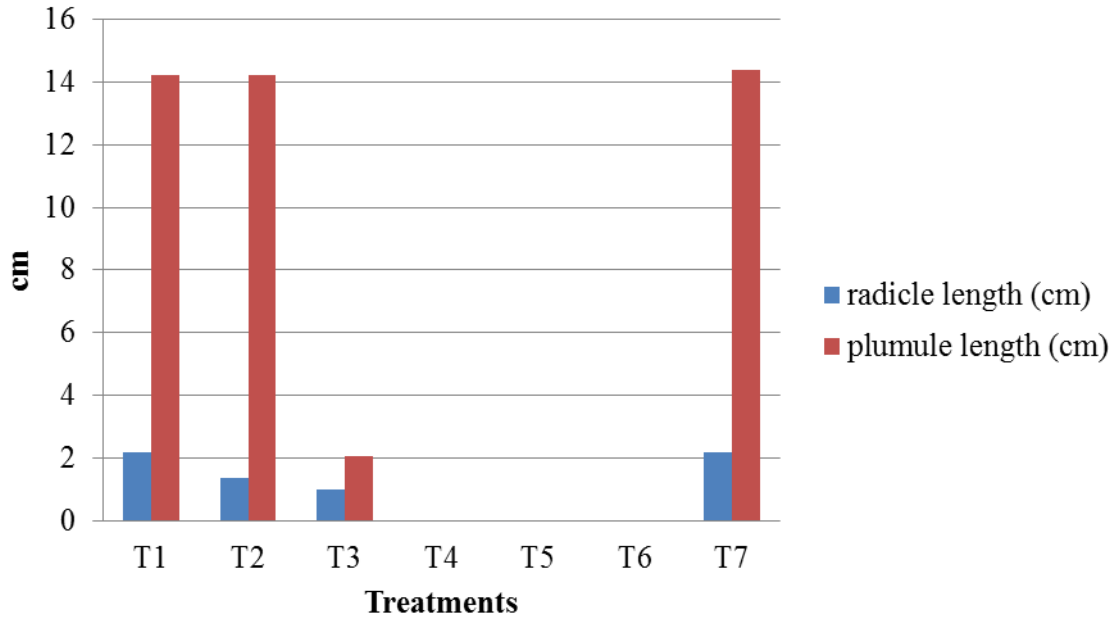


Fig. 14. Effect of different treatments on growth parameters of cow pea

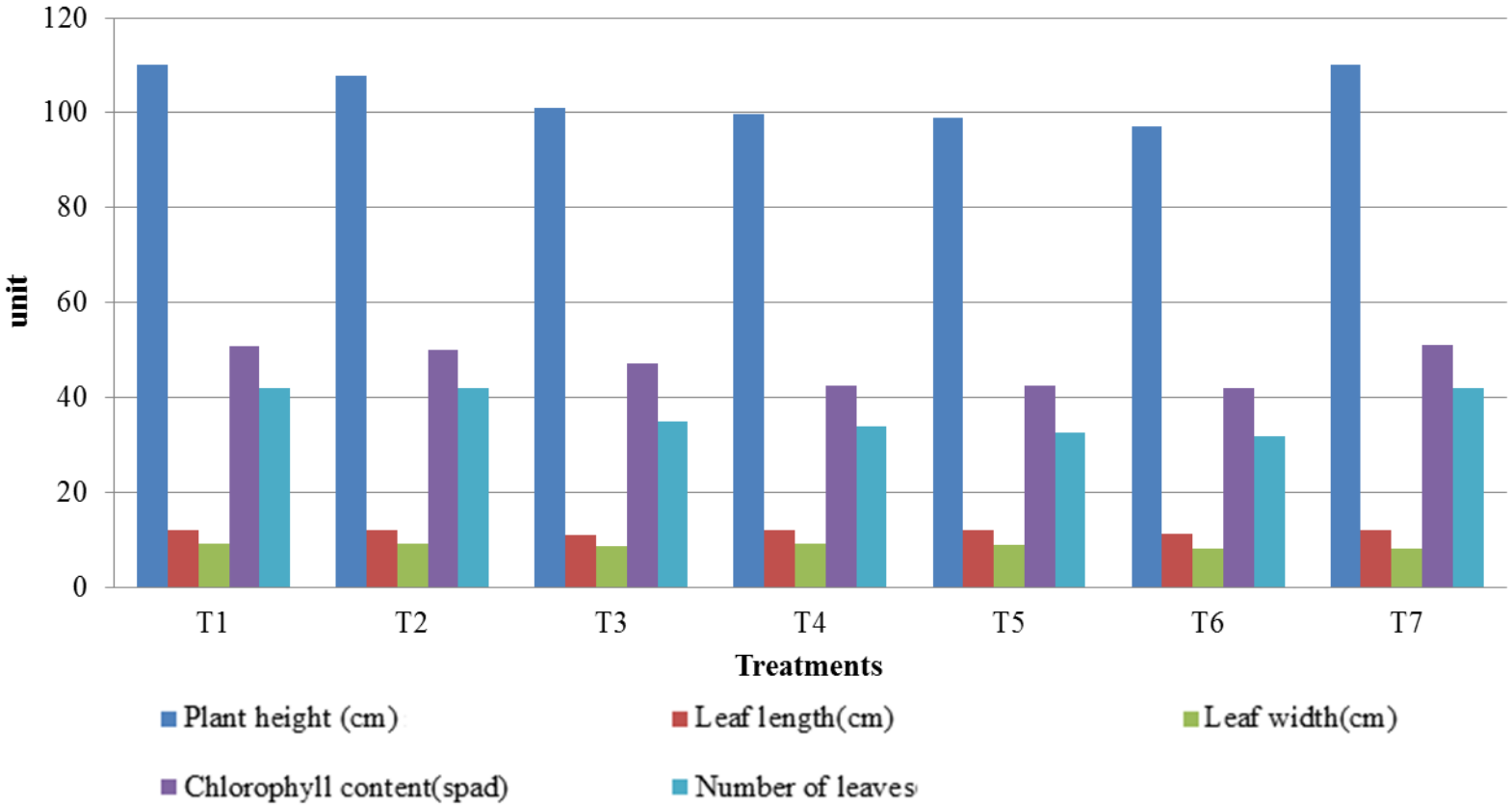


Fig. 15. Effect of different treatments on root weight of cowpea

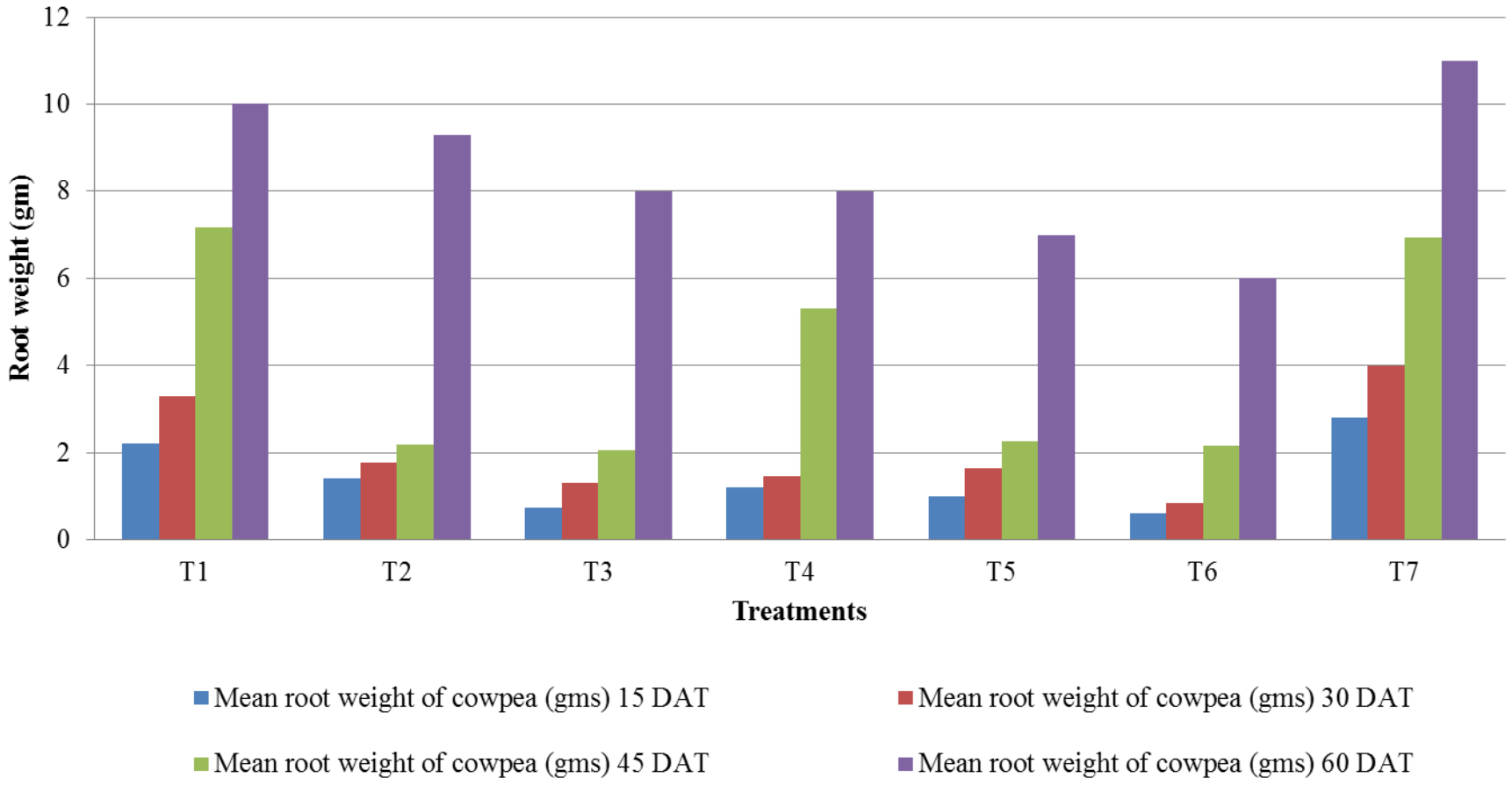


Fig. 16. Effect of different treatments on shoot weight of cowpea

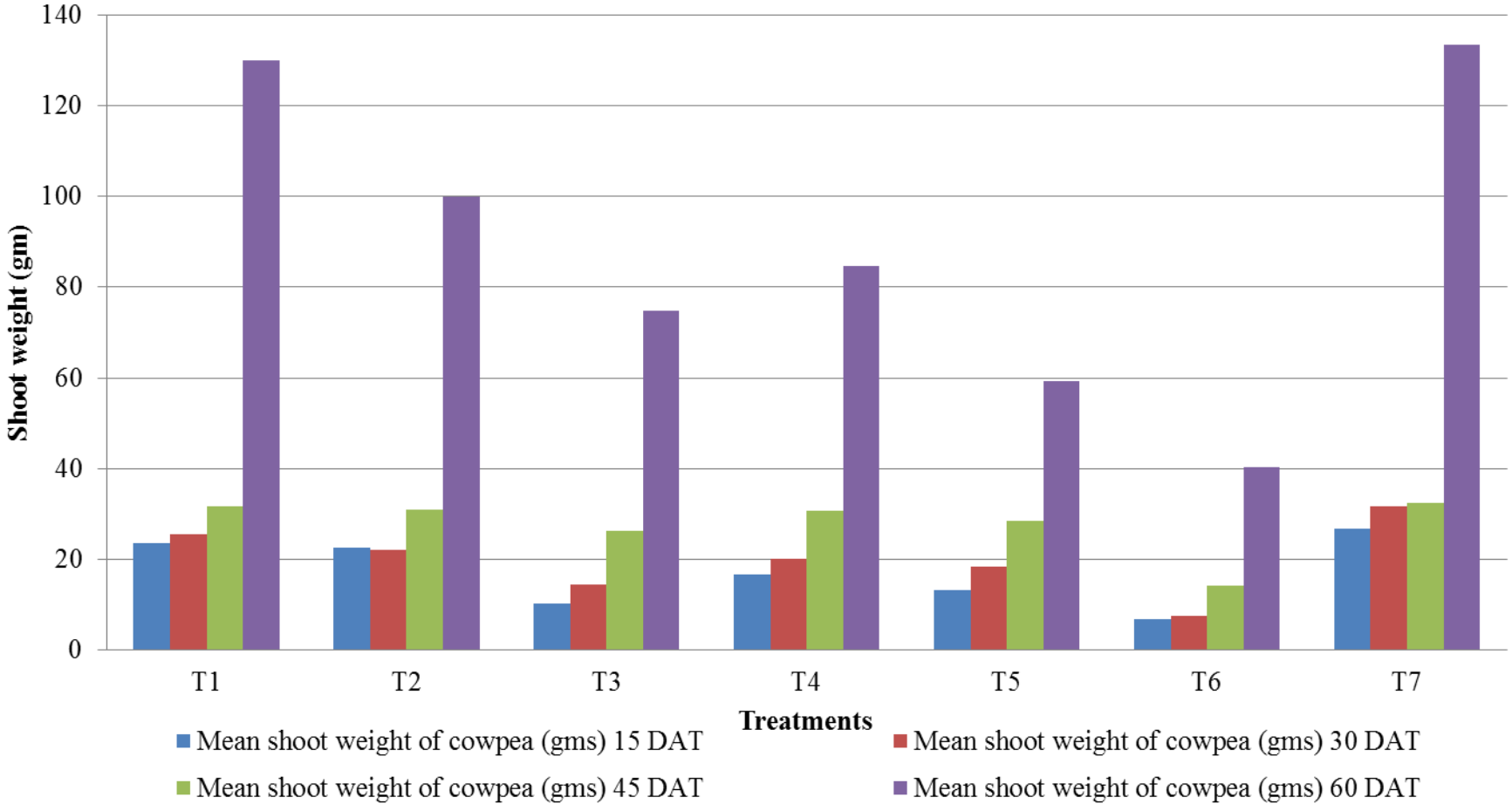


Fig. 17. Effect of different treatments on number of root nodules

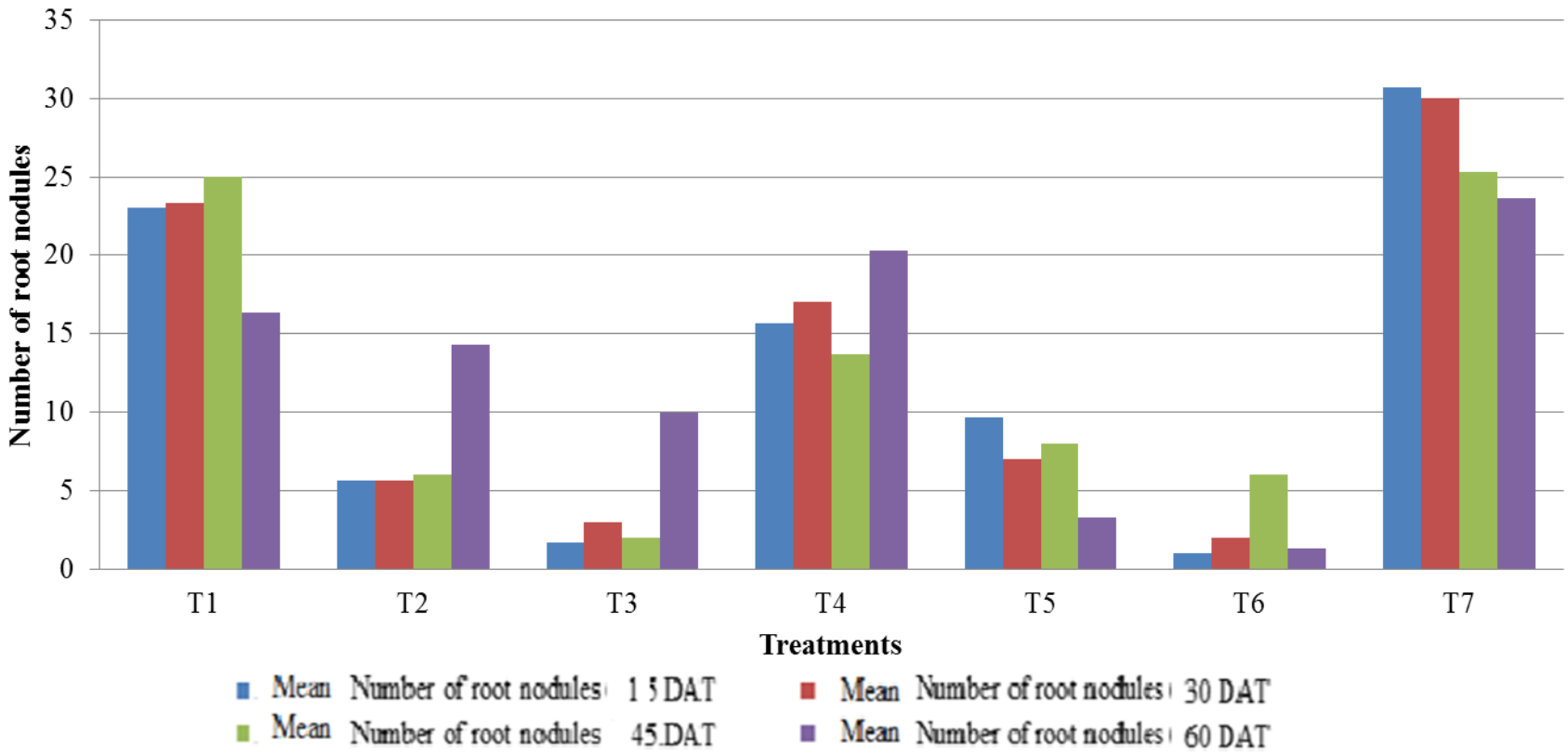
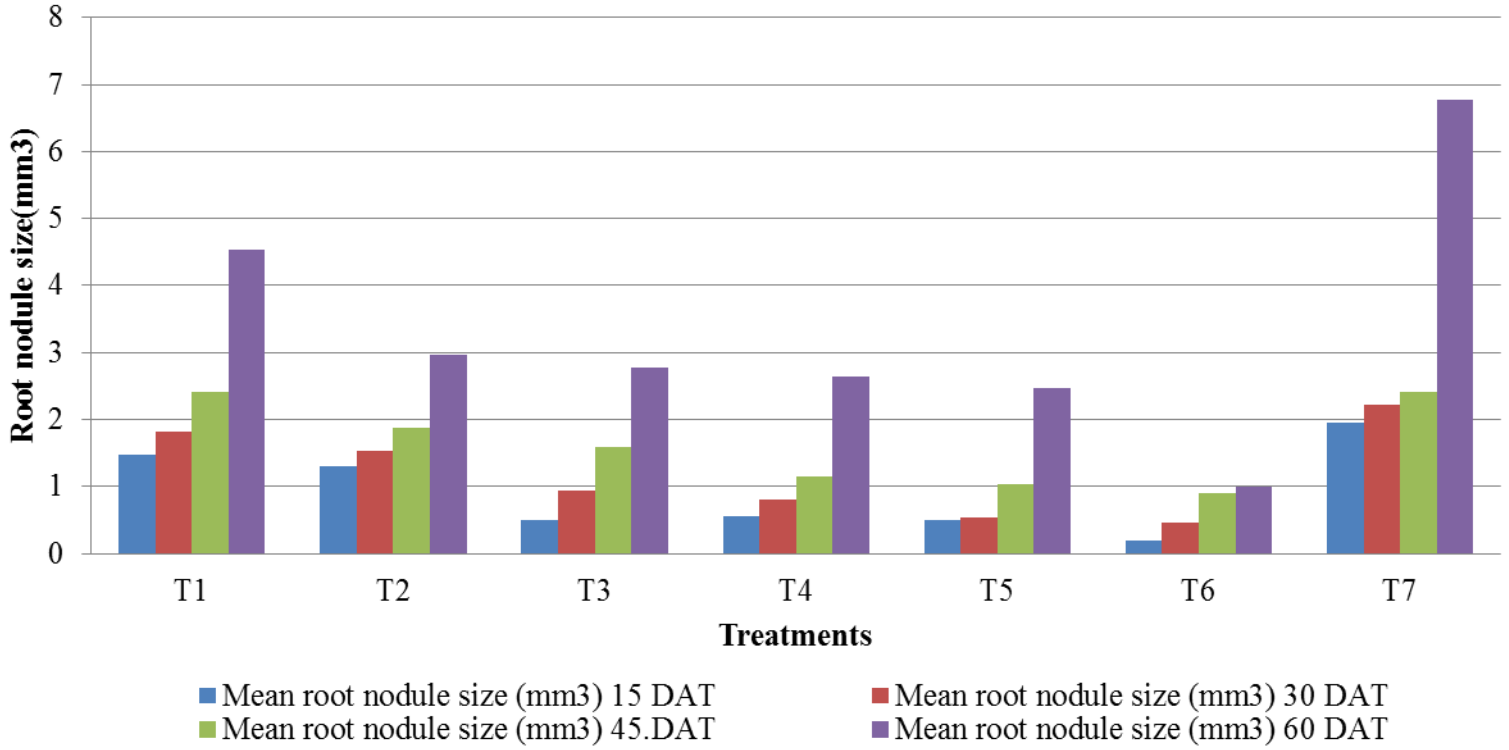


Fig. 18. Effect of different treatments on root nodule size of cow pea



SUMMARY

6. SUMMARY

The study entitled “Population dynamics and management of coconut root grub (*Leucopholis coneophora* Burm.)” was carried out to assess population dynamics of coconut root grub and to develop effective and eco-friendly management measures for this pest. The entire experiment is summarized below:

Total collection of adults was highest in mercury light trap (679) followed by ultra-violet light trap (553) and black light trap (286). Highest adult female collection was recorded in mercury light trap (96), followed by ultra-violet (65) and least in black light trap (35). The overall female: male ratio of collected adults was 1:7.7. Daily maximum and minimum temperature and soil temperature negatively and rainfall positively correlated with adult collection in light traps.

The larval population assessment data show that highest population of 29.96 per palm basin was in the month August 2013. From September onwards there was gradual reduction in larval population, finally reaching to 5.03 in February.

In the plastic cup experiments performed in the laboratory for the management of the pest, 100 per cent mortality was observed in Novaluron, Clothianidin, Azadirachtin 1500 ppm @ 5ml/L, 10ml/L, 15ml/L and Malathion which are on par with CNSL 2% (80 per cent) followed by Chlorpyrifos (66 per cent) and neem cake.

In the pot studies, maximum mortality of 98 per cent was observed in treatments with Azadirachtin 10ml/L and 15ml/L followed by Malathion with 97 per cent and Clothianidin with 87 per cent which are significantly better. Treatments with Azadirachtin 5ml/L (62 per cent), CNSL 2% with (58), neem cake, Novaluron (45), Chlorpyrifos (37), which were significantly low.

In the cage studies, the treatments viz. Azadirachtin 15ml/L gave the highest mortality (97 per cent) followed by Malathion (87), Clothianidin (73), Azadirachtin10ml/L (70) and Azadirachtin 5ml/L (63). The treatments with

CNSL (53 per cent), neem cake and Chlorpyrifos (30 per cent) were significantly inferior. Azadirachtin 15ml/L gave consistently higher mortality followed by Malathion 50 EC.

In the repellency studies, in the untreated sides grubs have eaten more quantity of potatoes when compared to the treated sides. In each treatment, the percentage repellency of treated and untreated sides was compared. In the treatment with azadarichtin 1500 ppm @ 5ml/L, the repellency was found non-significant. But there were significant differences in Azadirachtin 1500ppm 10 ml/L, 15ml/L and CNSL 2%. In no-choice test, the significantly highest repellency was observed in CNSL 2% (91.65 per cent) and Azadirachtin 1500ppm 10 ml/L, (89.20) followed by Azadirachtin 1500ppm 15 ml/L, (80.23) and least repellency in Azadirachtin 1500ppm 5 ml/L, (61.59). In starvation test, significantly highest repellency was observed in Azadirachtin 1500ppm 15 ml/L, (98.57 per cent) followed by CNSL 2% (89.60 per cent) and Azadirachtin 1500ppm 10 ml/L, (85.20 per cent) which are on par and least repellency was observed in Azadirachtin 1500ppm 5 ml/L, (78.68). CNSL 2% consistently repelled insect more when compared with all the three concentrations of Azadirachtin.

The results of phytotoxicty studies revealed that germination, plumule and radical length were significantly inhibited by CNSL 2, 4 and 6%. The treatment with Azadirachtin 1500 ppm 5ml/L and CNSL 2% had inhibited only to a low extent but with higher concentrations, there was significant inhibition of the growth parameters of cowpea.

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ABSTRACT

POPULATION DYNAMICS AND MANAGEMENT OF COCONUT ROOT GRUB (*Leucopholis coneophora* Burm.)

by

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ABSTRACT

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ABSTRACT

The population dynamics and management of coconut root grub (*Leucopholis coneophora* Burmister) was studied in the laboratory and field of College of Agriculture, Padnekkad, Kasaragod, Kerala during 2013-14. In the study on efficiency of light traps in collecting the adult beetles, the mercury light trap has recorded the prolonged collection, highest number of beetles and female beetles followed by ultraviolet trap and black light trap. The daily maximum and minimum temperature and soil temperature negatively and rainfall positively correlated with adult emergence. Larval population has shown a decreasing trend from August to February and highest larval population per coconut basin was 29.96.

Laboratory plastic cup experiments, field pot experiments and field cage experiments were conducted to develop management measures. In the plastic cup studies, 100 per cent mortality was observed in the treatments with Novaluron, Clothianidin, Azadirachtin 1500 ppm @ 5ml/L, 10ml/L, 15ml/L and Malathion which are on par with CNSL 2% (80) and Chlorpyrifos (66). In the pot studies, maximum mortality of 98 per cent was observed in treatments with Azadirachtin 10ml/L and 15ml/L followed by Malathion with 97 per cent and Clothianidin with 87 per cent which are significantly better. In the cage studies, the treatment viz. Azadirachtin 15ml/L gave highest mortality (97 per cent) followed by Malathion (87), Clothianidin (73), Azadirachtin10ml/L (70) and Azadirachtin 5ml/L (63). There was no mortality in absolute control. The EPN *Heterorhabditis indica* inflicted no mortality.

In no-choice test conducted to study the repellency of botanicals to root grub larva, significantly highest repellency was observed in cashew nut shell liquid (CNSL) 2 % followed by Azadirachtin concentrations. In starvation test, significantly highest repellency was observed in Azadirachtin 1500 ppm 15 ml/L. followed by CNSL 2%. In phytotoxicty studies, CNSL 2, 4 and 6% significantly inhibited the germination and growth parameters of cow pea.