MANAGEMENT OF THE RHINOCEROS BEETLE (*Oryctes rhinoceros* L.) ON COCONUT USING NEW GENERATION INSECTICIDES AND BOTANICALS.

by

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(2011-11-166)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Management of the rhinoceros beetle *Oryctes rhinoceros* L. on coconut using new generation insecticides and botanicals"** is a bonafied record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Management of the rhinoceros beetle *Oryctes rhinoceros* L. on coconut using new generation insecticides and botanicals"** is a record of bonafide research work done independently by **Sudhakar. S (2011-11-166)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Dedicated to my
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and my brothers

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LIST OF ABBREVIATIONS

Approx.	-	Approximate
^{o}C	-	Degree Celsius
%	-	Per cent
Cc	-	crown cleaning
CD	-	Critical difference
DAT	-	Days after Treatment
DP	-	Dispersible powder
et al.,	-	And others
Fig.	-	Figure
G	-	Granule
g	-	Gram.
ha	-	Hectare
i.e.	-	That is
No.	-	Number
Nos.	-	Numbers
NS	-	Not significant
POP	-	Package of practice
RH	-	Relative humidity
Sl.	-	Serial
Temp.	-	Temperature
Viz.,	-	namely

INTRODUCTION

1. INTRODUCTION

The coconut palm, *Cocous nucifera* L. eulogised as "Kalpa Vriksha" is one of the most useful trees to mankind and is grown in Asia, Pacific territories Africa, West Indies, Central and South America. The palm provides employment and livelihood to millions of farm families in the coconut growing regions of the world. Every part of the palm is useful. Coconut has an important role in nutrition, medicine, rituals and a host of other uses. In addition, the palm is an invaluable source of renewable energy. Among the coconut growing countries of the world, India has a pre-eminent position. Coconut is cultivated in eighteen States and three union territories in India.

The coconut palm has an inestimable link with the ethos, heritage and social milieu of the people of Kerala or "land of the coconut". Kerala has 43.00 per cent of the total area and contributes to about 38.00 per cent of total production in India. The coconut based farming system is the most common system in Kerala (Regeena *et al.,* 2004). The ubiquitous palm is raised in about 7.70 lakh ha in the State. However the productivity is a dismal 38 nuts per palm per year (Farm Information Bureau, 2013), whereas the yield in the other coconut growing States is much higher. Among the various reasons attributed to the low productivity, the infestation by pests and disease causing organisms is an important one.

The coconut palm is susceptible to the ravages of a large number of pests and diseases which attack the leaves, stems, flowers, nuts and roots. The pests include insects, mites, rodents, nematodes etc. The important pests in Kerala include the rhinoceros beetle (*Oryctes rhinoceros* L.), red palm weevil (*Rhynchophorus ferrugineus* F), coreid bug (*Paradasynus rostratus* Dist.), eriophyid mite (*Aceria guerreronis* Keifer.), and mealy bugs. Among the insect pests, the coleopterans are the most numerous (Child, 1974) and in this, the rhinoceros beetle, *O. rhinoceros* is a key pest. This beetle also attacks oil palm, pineapple, banana and ornamental palms.

The beetle breeds in the decaying organic debris, manure and compost pits in the vicinity of the coconut palms. Damage is caused by the adult beetles that bore into the unopened spindles and spathes. Attack on the central spindle results in reduction of leaf area which in turn affects the yield. When the petiole is bored and damaged severely, the whole fronds break off. The beetle also bores into the spathes and feeds on the tissues of the inflorescence inside. The infested spathes do not open and dry up. Yield loss of ten per cent due to rhinoceros beetle damage has been reported (Ramachandran *et al.*, 1963 and Nair, 1989). Rhinoceros beetle damage predisposes the palm to the infestation of red palm weevil and bud rot disease (Patel, 1988 and Howard *et al*., 2001). Renou *et al.*, (1998) stated that palms severely attacked by rhinoceros beetle could die or be damaged by secondary pests.

In Kerala, the coconut palms are raised mostly in the homesteads and small farms which makes comprehensive integrated pest management a difficult proposition. In a coconut based farming system, Thampan (1996) opined that integrated pest management could be conducted with the use of small quantities of chemical pesticides combined with mechanical and biological methods. Earlier organochlorine and other persistent pesticides were recommended for rhinoceros beetle control. Later on, other pesticides were applied which are not in use at present. In the Package of Practices (KAU, 2011) the Integrated Pest Management (IPM) recommendations against the rhinoceros beetle do not have a chemical pesticide tool.

In the present scenario, information on the profile of the coconut gardens, crop husbandry practices, incidence of the rhinoceros beetle and its extent of infestation, other pest and diseases on coconut in Kerala is limited. Even though, improved crop management practices including IPM have been developed in coconut, there are constraints in adoption of the same by the coconut farmers. Monitoring of the pest and adoption of recommended control practices are required to contain the beetle. The single stem unbranched architecture of the coconut palm adds to the cost of plant protection in Kerala. The dearth of skilled

labour coupled with lack of proper chemical and botanical pesticide recommendations have added to the woes of the coconut farmer. Newer chemical pesticides with novel modes of action and as well as botanical pesticides are being applied for pest control in crops like rice, banana and vegetables.

There is an imperative need for recommendations of new generation insecticides and botanical pesticides to control the rhinoceros beetle. This would be a boon and provide succour to the coconut growers of the State.

The present study has been envisaged to address the above issues. Research was undertaken with the following objectives.

1. To assess the intensity of damage caused by rhinoceros beetle in coconut.

2. To evolve management measures using new generation insecticides and botanicals against the rhinoceros beetle.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Among the pests infesting coconut, the rhinoceros beetle (*Oryctes rhinoceros* L.) is important. The beetle attacks the spindles and spadices of the palm which results in loss of yield and productivity. The infested palms are predisposed to other pests and diseases. In this context, an attempt has been made to review the available literature on socio economic issues and constraints in cultivation of crops like coconut and other crops, damage and yield loss caused by the rhinoceros beetle and its management.

2.1 Socio-economic issues and constraints in cultivation of crops.

In a study on labour efficiency in Kerala, Padmanaban (1981) observed that only 14.2 per cent of respondent agricultural labourers were having good knowledge of scientific agriculture.

High labour consumption and lack of good quality seedlings were identified as the most important constraints in increasing coconut production in Kerala (Vijayakumar, 1983).

The non-availability of inputs and plant protection equipments in time, non- availability of labour, high cost of labour and materials involved were the constraints experienced by contact farmers for adoption of messages on coconut cultivation (Prasannan, 1987).

According to Prakash (1989), lack of cultivation of hybrid varieties, low adoption of chemical fertilizers, pest and disease incidence, low labour productivity and high wage rate were the constraints experienced in coconut cultivation.

Bastine *et al.,* (1991) reported on the poor adoption of improved technologies by coconut farmers in North Kerala. The constraints were non availability of planting materials of hybrid varieties in time and insufficient number and high cost of labour and chemicals. Similar observations were made

by Jnanadevan and Prakash (1994) in a study of the development programmes of the Coconut Development Board in Alappuzha district.

Julian *et al.*, (1991) observed that most of the marginal and small farmers possessed only medium level of knowledge about integrated pest management practices in coconut and only 2.50 per cent of marginal farmers and one fourth of small farmers had high level of knowledge.

Muliyar *et al.*, (1993) reported that in Muttathody village in Kerala, most of the farmers' constraints were identified as lack of irrigation facilities, irregular spacing, high cost of labour, very small holding size and lack of cooperative ventures. Most of the farmers did only part time farming as the income from agriculture was not sufficient for their livelihood.

Sakeer (1994) in a study on understanding the socio economic profile of agricultural labour in Trivandrum district observed that majority of the respondent climbers had only a limited knowledge about plant protection measures in coconut.

In Kerala, the average size of the holding was less than 0.20 ha (Alexander and Peter, 2005). They observed that 215 palms are there in a ha of land in Kerala though the recommendation is only 175 palms in pure plantations. The high density of palms with closer spacing in the coastal regions contributed to higher percentage of infestation by pests.

Mahadik *et al.*, (2009) observed that in Konkan region of Karnataka, 42 per cent of farmers adopted the recommended spacing of 7.5 x 7.5.m. Twelve per cent adopted proper fertilizer recommendations and 40 per cent undertook recommended irrigation practices. Only sixteen per cent adopted plant protection measures against the rhinoceros beetle. The hooking out of beetles and leaf axil filling with sand and insecticides were undertaken. The adoption was low due to lack of knowledge, shortage of labour and high cost and non - availability of inputs.

Jnanadevan, (2013) observed that most of the holdings were less than 0.1 ha in Kerala and only few farmers possessed holdings of size above 0.40 ha. High labour charges and rainfed farming condition forced the farmers to ignore the timely adoption of agronomic practices. This has resulted in neglect of adoption of management practices leading to low productivity. The application of inorganic fertilizers at the recommended level was practised only by few farmers. Plant protection and fertilizer application in coconut have not been adopted on a wide scale. Low level of adoption was attributed to hardship in getting trained plant protection personnel and high cost of fertilizers. The difficulty in deploying trained climbers in time and high cost of labour were also related issues.

2.2 Infestation by rhinoceros beetle on coconut

After the first description of the rhinoceros beetle in the last decade of the nineteenth century, it has been studied by a number of scientists like (Stebbing (1903), Lefroy (1906), Fletcher (1914), Pillai (1919) and Ayyar (1919 a). The pest, its damage and control aspects have also been investigated in Sri Lanka, Myanmar, Phillipines, Indonesia, Africa and the Pacific Islands. Menon and Pandalai (1958) have listed the scientists who have contributed to the understanding of the beetle.

Survey of the rhinoceros beetle in Travancore-Cochin in 1954 indicated that the attack was very severe on either side of the new railway track from Quilon to Ernakulam where a large number of coconut palms had been felled and the stumps left behind. These stumps served as suitable sites for the prolific breeding of the beetle (ICCC, 1956).

Cumber (1957) classified the ecology of the rhinoceros beetle. He divided the damage of *Oryctes* into three groups, dead, severely damaged and little damaged. In severely damaged palms, the production of nuts was reduced to about 10 per cent or less and in the less damaged group, there was no apparent effect on the yield due to the beetle attack.

Ramachandran (1961) reported the rhinoceros beetle bored into the unopened leaf and as the leaf opened, a portion of the leaf would be missing. The beetle bored through the outer covering (spathe) of the spadix and fed inside the tissue. The infested spadix did not open and dried up. Presence of holes in the spathe was therefore a sure sign of beetle attack. A leaf with at least one notch or a spathe with a hole was considered as one attacked leaf or spathe irrespective of the number of notches or holes.

Sison (1957) stated that the palms with 50 per cent of all their fronds damaged had about one fifth the number of developing nuts that were found on normal palms. Many immature nuts were dropped from the damaged palms.

Ramachandran *et al.*, (1963) reported a loss in yield of 5.5 to 9.1 per cent due to beetle attack. From artificially pruned leaf damage stimulation studies, it was observed that damage to 50 per cent fronds corresponded to leaf area reduction of 13 per cent lead to decrease in nut yield by 23 per cent.

Hinckley (1967) stated that each feeding visit of the beetle caused either petiole or leaflet damage to three of four fronds of coconut palms in the Pacific islands.

One attack by rhinoceros beetle increased the likelihood of further attacks (Bedford, 1975, Young, 1975), *ie.*, certain palms were more frequently attacked than would be expected by chance. Gressitt (1953) stated that more than one beetle might attack a palm at the same time, while a neighbouring palm might not be attacked. In infested areas in India, five to six beetles have been found feeding in the same crown (Nirula, 1955 a).

The time taken from initial penetration by the beetle until the damage first became visible from the ground averaged 41 days and it was 113 days before all damage became visible (Young, 1975).

In India, damage of inflorescence in coconut was also reported in severely infested areas which caused reduction in yield up to 10 per cent. The adult palm was killed if the central growing primordium was destroyed (Nair, 1975).

In Papua New Guinea, an average immigration rate of rhinoceros beetle into a study site of young palms was determined by Bedford (1980) . Results indicated that there was no annual cycle or overall trend but it was reduced by rain and male : female sex ratio was 0.91. Rather than attempting to measure the population directly, as the damage becomes obvious as the fronds open (at approximately one frond per month), methods for measuring damage as an index of the population were developed (Young, 1975).

Studies conducted by Food and Agriculture Organization (1978) revealed that in a rapid survey method in the Pacific islands of Fiji, Tonga and Western Samoa, only the central three to five fronds of the crown, *viz*., the most recently opened ones were considered. Palms were scored as either damaged in these fronds or undamaged; the total number of fronds damaged was ignored.

Bedford (1980) reviewed two methods of assessing the rhinoceros beetle damage. In the detailed type of survey, random samples of 20-30 palms at various sites were marked. The total number of fronds as well as those with beetle cuts were recorded periodically. The results were expressed as the percentage of fronds damaged at sites or group of sites combined. In the rapid survey method, only the young central three to five fronds were observed. Palms were scored as either damaged in these fronds or undamaged. At a given locality, four observation points were selected and from each point, 25 palms were observed for central crown damage. The results of the four observations were pooled to give percentage of palms damaged in the area.

Patel (1988) observed that when the height of coconut palm increased the infestation of rhinoceros beetle decreased.

Surveys on rhinoceros beetle damage in Lakshadweep in the eighties indicated a leaf, spathe damage as well as fresh incidence of spindle damage of 56.60 per cent, 31.10 per cent and 39.20 per cent, respectively (CPCRI, 1989).

Pillai *et al.*, (1993) reported that the intensity of damage could be assessed in terms of the number of infested palms, leaf damage, fresh incidence on the spindle and the number of beetles present on the crowns of palms.

Damage to spathes by the rhinoceros beetle was reported to reduce the yield in coconut to the tune of 5.70 per cent by Nair and Visalakshi (1999) .

In a study on immigration and activity in *O. rhinoceros*, Norman and Basri (2004) monitored damage to immature oil palm at about two to three months intervals, starting from 1997. Four palms adjacent to each palm were assessed. The number of damaged fronds were counted and divided against the total number of fronds to derive the damage percentage. The relative density of beetles was closely related to the damage inflicted on the palms.

In Dindigul district of Tamil Nadu, Ottanchathiram block had the highest per cent infestation of rhinoceros beetle of up to 14.50 per cent followed by Sanarpatty (8 per cent) and Thoppampatty (8 per cent), Attur (7 per cent) and Palani (5 per cent). In Sivagangai district among the eleven blocks surveyed, Singampunari block recorded the highest infestation of up to 15 per cent followed by Thirupathur (14 per cent), Kallal (9 per cent), Manamadurai (9 per cent), Devakottai (8.4 per cent) and Kannangudi (7.3 per cent) (AICRP, 2006).

A survey on the infestation of the coconut rhinoceros beetle was undertaken in eight districts of Tamil Nadu in 2011-12. The mean per cent damage of coconut rhinoceros beetle was found to be the highest in Sivagangai district (22.00 per cent), followed by Namakkal (16.60 per cent), Dindigul (13.39 per cent) (AICRP, 2012).

2.3 INFESTATION BY OTHER PESTS AND DISEASES IN COCONUT.

Apart from the rhinoceros beetle, the other important pests include coreid bug (*Paradasynus rostratus* Dist.), eriophyid mite (*Aceria [Eriophyes] guerreronis* Keifer.), mealy bugs (*Dysmicoccus brevipes* Cockerell and Pseudococcus longispinus Targioni-Tozzetti) and red palm weevil (*Rhynchophorus ferrugineus* F.). Two important diseases of the coconut palm are bud rot caused by *Phytopthora palmivora* and leaf rot caused by a complex of fungi *viz., Colletotrichum gloeosporioides, Exserohilum rostratum* and *Gliocladium vermoeseni, Fusarium solani, F. moniliforme* var. Intermedium and *Thielaviopsis paradoxa*.

Coreid bug (nut crinkler)

The coreid bug was first collected from Bombay and later placed in the new genus *"Paradasynus"* in 1934. In Kerala, the bug was first observed on coconut in 1959 and identified by Kurian *et al.,* 1976. During the last decades of the twentieth century, this pest had become serious in Kerala and spread to Tamil Nadu and Karnataka. The feeding by nymphs and adults on the nuts are manifested by necrotic lesions which later take the form of furrows and crinkles. The bionomics, population dynamics and management by the pest has been investigated by a number of workers. It is one of the major pests of Kerala and has other alternative hosts like guava, cashew and neem (Paul, 2006).

Eriophyid mite

The eriophyid mite was first described in 1965 from Guerrero State, Mexico. Later it spread to Venezuela, Puerto Rico, West Indies, Pacific Islands, Africa, Indonesia, Philippines, India and other coconut growing countries. The mite was first reported in Kerala in 1998 and later spread to other coconut growing states. Mites live in colonies beneath the perianth of coconut buttons. Desapping by mites result in the production of white patches which later become brown as the nuts develop. The infested buttons either drop or develop into small

poor quality coconuts. Several scientists have worked on the population dynamics, seasonal influence, dispersal, yield loss and management of the mite in the tropical countries where coconut is raised. An integrated pest management schedule has been worked out under the National Agricultural Technology Project on coconut eriophyid mite (Naseema *et al.,* 2004). The recommendations were published in the Package of Practices (KAU, 2011).

Mealy bugs

The presence of *P. longispinus* on coconut leaves was reported by Ayyar (1919 b). Earlier the mealy bugs were considered as minor pests (Mathen *et al.,* 1962) but later were identified as serious pests inflicting heavy damage (Radhakrishnan, 1987). Anithakumari *et al.,* (2003) reported that mealy bugs were important pests of coconut in Thiruvananthapuram district. (Bindu 2003) studied the biology, damage and yield loss caused by two species of mealy bugs on coconut. Heavy feeding by the pest causes deformed and suppressed heart leaves and drying of spadix. Mealy bugs have been reported to be serious in Kerala especially during the summer months. Management of the mealy bugs by cultural and chemical methods have been recommended by Bindu (2003) and KAU (2011).

Red palm weevil

Information on red palm weevil was first published in India in 1891. This pest was first described as a serious pest of the coconut palm in 1906. It is a pest of other crops like date palm, oil palm and other palms. The pest is a concealed tissue borer. The typical symptoms are bore holes on the palm with ooze of brownish fluid and yellowing of inner leaves. The weevil is capable of causing severe damage resulting in death of the palm (Menon and Pandalai, 1958 and Child, 1974). In India, scientists like Nirula K.K., Menon K.P.V., Abraham V.A., Kurien C., Pillai G.B. and Mathen K. are earlier workers who have contributed to the understanding of the weevil and its management (Nair and Visalakshi, 1999). In later years, experiments for IPM against the weevil were conducted by CPCRI

and KAU. The results have been used to chalk out an IPM strategy to contain the red palm weevil (KAU, 2011).

Bud rot disease

The occurrence of bud rot was first recorded in coconut in 1834 at Grand Cayman. Later it was reported in India, Sri Lanka, East Africa, Trinidad, Fiji and the Philippines. Butler reported that the causal organism was *P. palmivora* . The disease effects palmivora and arecanut also. (Menon and Pandalai 1958). The symptomatology, epidemiology and management of the disease has been studied in the coconut growing countries. The disease is more prevalent during monsoon season. In seedlings, the spear leaf becomes pale and comes off with the pull. In adult palms, the leaf base rots and later affects the meristem, If not treated, the disease can become fatal. At present, bud rot is a major disease of coconut in Kerala. An integrated disease management strategy has been recommended by Peethambaran *et al.,* (2008) and KAU (2011).

Leaf rot disease

This disease has been reported since 1880 s in India and was also observed in West Indies and New Guinea. Even though the organism was isolated in 1916, it was only during 1930 s – 1950 s that a number of associated fungi were isolated. The pathogenicity, symptomatology and management has been studied by a number of workers (CPCRI, 2000). The causal organisms affect the coconut palms especially those below 25 years. Water soaked lesions on the spindle leaves turn brown and blown away in the wind. The intensity of the disease is more in monsoon. Surveys have revealed that 14 to 65 per cent of the palms in Kerala have been affected by leaf rot. An integrated disease management strategy to check the leaf rot has been recommended (CPCRI, 2000 and KAU 2011).

2.4 Damage to other crops by rhinoceros beetle.

Gressit (1953) stated that in the Palau islands, the rhinoceros beetle became a serious pest of screwpine. It could maintain its population on this host from where it has severely infested and exterminated the coconut palms.

Besides coconut, the rhinoceros beetle was capable of attacking other palms also. The most important are the palmyra palm, the toddy or wild date palm and African oil palm. The other host plants included date palm, areca palm, the sago palm, the nipa palm, the sugar palm, the fan palm, the sardang palm, the talipot palm and other ornamental palms. It has also been reported on agave, sugarcane, pineapple, tree fern, banana and taro but these appeared to be only accidental hosts (Menon and Pandalai, 1958).

Bedford (1968) reported that African rhinoceros beetle (*Oryctes simiar* Coq.) bored into the leaf bases of banana plants in Madagascar.

Mariau (1968) observed that on young oil palms, the beetle only needed to burrow a short distance in order to reach the growing point and kill or severely deform the palm. Attacks on older palms were rarely lethal. In young plantations certain palms were attacked repeatedly while similar sized neighbours were not infested. This could be due to the attraction of beetles to odours from the damaged tissue.

Wood (1968) observed that the adult rhinoceros beetle bored into the crown or heart of the oil palm or into the base of the cluster of unopened fronds (spear) of young oil palms, damaging several of the still-unfurled fronds as it fed on the sap. The damaged fronds showed characteristic V- or wedge-shaped cuts as they unfolded, reducing the photosynthetic area. Severe repeated attacks killed the growing point, resulting in the death of the oil palm. The effects of damage by the rhinoceros beetle could be much more severe, often lethal, on young oil palms (less than a year old) than on more mature ones. He classified the damage caused

by the rhinoceros beetle in oil palm into five categories. They were apparently dead, heavy, medium, light and nil.

In surveys conducted in New Caledonia, oil palms in a sampling grid (one row in ten) were classified once in a month as ‘yes’ or ‘no’, depending on whether unopened spears show sign of attack (Young, 1971).

The coconut rhinoceros beetle infested the unopened spathes of arecanut (Nair, 1975).

Dhileepan (1988) observed that in India, the infestation of oil palm by rhinoceros beetle was more prevalent in a mature plantation (10-15 years old) compared to immature or younger plantings.

A national survey conducted on *Oryctes rhinoceros* in Malaysia has indicated that most oil palm estates had reports of occurrence of *O. rhinoceros* adults within one to six months after replanting (Norman and Basri, 1997).

Regupathy *et al.,* (1997) stated that rhinoceros beetle bored at the base of the stem of pineapple which resulted in wilting of the plant.

The coconut rhinoceros beetle has occasionally been recorded on banana, sugarcane, papaya, sisal and pineapple (CPC, 2011).

2.5 Weather parameters and rhinoceros beetle incidence and damage.

Menon and Pandalai (1958) reported that in the west coast of India where the dry weather was prevailing, a large number of beetles emerged in the evening of rainy days.

Mariau (1967) studied that the presence of African rhinoceros beetle (*Oryctes boas* F.) from crowns of palms in the Ivory Coast showed marked regular fluctuations, with maximum catch in the dry season and minimum in the wet season. Male:female sex ratio was 0.25. Fluctuations were similar in different plantations.

In New Britain, Bedford (1975) reported that rainfall increased the rhinoceros beetle captures.

In the Philippines, Zelazny and Alfiler (1987) observed that nightly rainfall increased captures of rhinoceros beetle in coconut log traps. Similar observations were made in experiments on oil palm in Malaysia by Norman and Basri (2004).

Rhinoceros beetle occurred throughout the year, but during the summer months their population was at peak levels. This was mainly due to temperature -humidity conditions becoming progressively favourable for the pest and unfavourable for the associated natural enemies. Distinct seasonal peaks were not observed for rhinoceros beetle but their numbers were relatively higher during the rainy season (Rao, 2003).

Based on weather and pest studies, Norman and Basri (2004) observed that there was a significant relationship between rainfall and flight occurrence, which likely indicated that rainfall may have induced the beetle to fly searching for moist breeding sites. The beetles were reported to be most active during rainy period.

2.6 Monitoring of rhinoceros beetle using pheromone traps.

An aggregation pheromone, ethyl 4-methyloctanoate was stored in small heat sealed polymer membrane bags and placed on top of interlocking vanes mounted on a plastic bucket. The rhinoceros beetles attracted by pheromone were trapped in the bucket. The pheromone trap @ one for every two ha was effective for monitoring as well as control of the beetle (Wood, 1968).

Barber *et al.,* (1971) demonstrated that ethyl dihydrochrysanthemumate (chrislure) applied in metal vane, traps was an effective attractant for *O. rhinoceros.* When applied to the much cheaper coconut cap traps, more beetles were caught than in metal traps (Bedford, 1973). Subsequently, the commercially

available and cheaper ethyl chrysanthemumate (rhinolure) was found to be effective (Maddison *et al.,* 1973). Turner (1973) suggested the use of traps containing 0.2 ml ethyl chrysanthemumate at 25 traps per ha.

Rhinolure with an olfactory reinforcer was tested (four traps per ha) against the African rhinoceros beetle *Oryctes monoceros* in coconut palm in the Ivory Coast. More beetles were caught by traps at the plantation borders and when the breeding sites were covered by vegetation, the traps apparently imitated the odours of natural breeding sites (Julia and Mariau, 1976).

Monitoring with pheromone gave an indication of the pest and could provide the basis for a control intervention. Catches from traps with pheromone could be used with meteorological data as input for phenological models to predict the flight activity of pests (Knight and Croft, 1991).

Ethyl 4-methyloctanoate has been reported as an effective male aggregation pheromone of *O. rhinoceros* (Hallet *et al.,* 1995 and Morin, *et al.,* 1996). Purba *et al.,* (2000) opined that ethyl 4- methyloctanoate was a powerful attractant for *O. rhinoceros.*

Morin *et al.,* (1996) reported that more females than males were caught in the traps containing the pheromone ethyl 4-methyloctanoate. However Alfiler (1998) observed that male and female beetles were caught in almost the same frequency in traps containing the above pheromone alone or in combination with coconut wood. He also showed that there were no significant difference in the proportion of females and males caught in traps containing the pheromone.

Howse *et al.,* (1998) and Inscoe *et al.,* (1990) reported that aggregation pheromones were attractive to both sexes and were best understood in Coleoptera. They operated over a long range and offered good potential for mediating pest attack.

Morin *et al.,* (2001) reported *O. rhinoceros* trapping was possible with the pheromone (ethyl 4-methyloctanoate) as the attractant in a new type of trap. This trap could function without insecticides or water, and could remain in place for several months without any particular maintenance so long as the attractant does not run out. As the trap was two metres tall, it offered the advantage of having the silhouette of a palm stem, which was visually attractive to the beetle.

Based on experiments with double-vane traps in an oil palm plantation in Andhra Pradesh, Kalidas (2004) found that the pheromone evaporated quickly on days when temperatures were above 33.5°C, reducing its longevity, and some adults attracted to the traps were not caught and could attack nearby palms. In this case the traps were not considered economical. These results suggested that the economic advantage of trapping could vary with location.

Allou *et al.,* (2006) working with *O. monoceros* attacking coconut in the Ivory Coast found that addition of rotting coconut material to oryctalure-baited vaned bucket traps significantly increased trap catch by about three times. They also found that vertical tube traps baited with oryctalure plus rotting coconut material significantly outperformed similarly baited vaned bucket traps.

Pheromone - RB lure, (PCI) traps in Alappuzha recorded an average catch of seven to eight beetles per month. Post treatment observations after one year indicated 43-47 per cent reduction in leaf damage and 60-80 per cent reduction in site occupancy by the pest (CPCRI, 2013). Nanomatrix loaded with pheromone trapped the maximum (105) beetles per trap. Polymer membrane dispenser containing 800 mg of pheromone trapped 72 beetles per trap. The pheromone loaded in nanomatrix had a slower release rate compared to the commercial lure in polymer membrane. Studies on optimum trap density revealed that one trap per ha was ideal, but if the population load of the pest was high, then two traps per ha could trap the beetles better (CPCRI, 2013).

2.7 Management of rhinoceros beetle

Cultural methods

Leefmans (1920) and Corbett (1932) recommended the burning or deep burying of the breeding materials to control the rhinoceros beetle. However Nirula (1955 b) advocated suitably treating the breeding places with insecticides like BHC.

Cherian and Ananthanarayan (1939), Gressit (1953), Sison (1957), Menon and Pandalai (1958) suggested that removal of waste materials from the field should be done regularly and phytosanitation should be maintained in the gardens. In young palms, the beetles are extracted from feeding holes with the help of long rods hooked at the tips.

Owen (1961) suggested the use of vegetative barriers which interfered with the proper feeding, breeding and flight of rhinoceros beetle in Malaysia. Similar observations were made by Julia and Mariau (1976) in the Ivory Coast.

Mechanical methods

Gressitt (1953) reported from the Palau islands that the male beetles apparently made more flights during the dispersal period since more number of male beetles were caught in the stump traps. The total catch during the period between October 1964 and December 1966 included 3049 male beetles and 1988 females.

Menon and Pandalai (1958) reported that hooking out the beetle using beetle hook was useful in controlling pest damage. Similar observations were made by Pradhan (1969) who recommended hooking out the adult while it was feeding in the crown. A special metallic rod which was 75 cm in length with a hook at one end and a grip ring at the other was used for this purpose.

An *O. rhinoceros* eradication programme in two islands in Fiji was highlighted by Bedford and Maddison (1972) Some 506 coconut cap rhinolure traps were operated on Vomo (109 ha) and 317 traps on Bekana (16 ha) from December 1971 to the end of February 1974; 3644 beetles (1626 males and 2018 females) were removed from Vomo and 2462 from Bekana (1082 males and 1380 females).

Traditional methods of controlling rhinoceros beetles included removal of beetles from feeding holes in young palms. (Bedford, 1980 and Young, 1986)

With a view to reducing pest populations by olfactory trapping, field trials were carried out by Zelazny and Alfiler (1987) in the Ivory Coast to assess the efficiency of two synthetic aggregation pheromones: ethyl 4-methyloctanoate and 4-methyloctanoic acid. Trapping over six months in 2002 and 2003 in 19 ha coconut plot inside a 4,000 ha oil palm estate reduced damage from 3.80 per cent in 2001 to 0.50 per cent in 2002, then to 0.20 per cent in 2003. Damage was not observed in 2004 with routine trapping using 32 traps, which caught 3369 beetles in nine months.

In the Ivory Coast, manual method of extraction of adults was reported by Echimane *et al.,* (1992) to be highly labour intensive and was impossible in tall standing palms. Frequent insecticide applications were only possible in agro industrial sectors, but they entailed serious environmental risks.

Boiled castor cake with a little bit of oil was mixed with water and taken in earthen pots and placed in coconut gardens to attract and trap rhinoceros beetles (Baskaran and Narayanasamy, 1995 and Unnikrishnan, 2012).

In oil palm, pheromone traps could be used integratedly for the dissemination of biocontrol against rhinoceros beetle (Ho, 1996). Chung (1997) evaluated and recommended the use of pheromone traps to reduce damage in oil palm by rhinoceros beetle.

Nair *et al.,* (1997) recommended periodical examination of the coconut crown and extraction of the adult beetle by means of a metal rod about 0.5m long with a hook at one end during peak periods of pest abundance (June-September).

Didier *et al.,* (2002) investigated the nature and role of the male pheromone emitted by the Dynastid beetle (*Scapanes australis*) to develop a mass trapping technique against this major coconut pest in Papua New Guinea. Plant pieces, either sugarcane or coconut when used along with pheromones enhanced captures. Traps with the pheromone caught both sexes in a 3:2 female–male ratio.

Ponnamma, *et al.,* (2002) studied with the potential benefit of the aggregation pheromone - PO 466 Sime RB Pheromone (I lure-ethyl-4-methyloctanoate - 980 mg), for *O. rhinoceros* in oil palm plantations in Thodupuzha, Kerala. The traps were set @ one trap per two ha (Total -10 traps). A total number of 1338 beetles were caught in the traps within a period of 25 months which resulted in a very high reduction in population of beetles. The sachets were effective for three to four months during summer and for five to eight months during monsoon periods with an average of five months. The damage on leaf, petiole and spindle was brought down from 7.16 to 6.96, 0.33 to 0.20 and 0.20 to 0.02 per palm respectively. Bunch infestation was reduced from a level of 35.00 per cent to 0.001 per cent within a period of 25 months.

Norman and Basri (2004) advocated the use of pheromone traps to determine hot spots for targeted chemical control of *O. rhinoceros* in oil palm. This could avoid blanket application of chemicals which could save management costs.

Soaking of castor cake at one kg in five litres of water in small mud pots and placing them in coconut gardens to attract and trap the adults was advocated by Ramaraju and Pretheep kumar (2005).

As part of integrated control of the rhinoceros beetle in the Philippines, PCARRD (2006) recommended the placement of light traps in the centre of coconut plantations.

USDA–APHIS (2008) reported that ground surveys and attractive traps were used in Guam as part of quarantine and eradication programmes against coconut rhinoceros beetle by Guam department of agriculture.

Jayanth *et al.,* (2009) demonstrated the use of bucket traps in coconut plantations to catch a high percentage of unmated females and opined that mass -trapping was beneficial in reducing beetle populations.

In Tunisia, Soltani (2009) studied the effectiveness of the use of one light trap in 3.5 ha to catch the rhinoceros beetle *Oryctes agamemnon arabicus* on date palm for three years. More than 550 adults were trapped per season of activity from June to mid-October. He also reported that organic heaps operated as traps by attracting a large number of beetles, particularly females, which laid their eggs and subsequently contributed largely in the decline of the pest population inside plantations and their impact on the palm trees.

Russell (2011) reported on the removal of all adult beetles from bore holes, frond bases, or other visible areas in a rhinoceros beetle eradication program in Guam.

Installing pheromone traps (PVC pipe of dimension 11 cm diameter and 1.5m height) using pheromone Oryctalure at one per ha for collection of adult beetles (Nair *et al.,* 2011; Chandrika and Josephrajkumar, 2013).

Josephrajkumar *et al.,* (2012) recommended the setting up of Oryctalure - pheromone trap at the rate of one in five ha to trap the rhinoceros beetle.

For capturing rhinoceros beetle adults, light traps are to be set following the first rains in summer and monsoon period. Rhinolure traps have also to be set at the rate of five traps per ha. (TNAU Expert System, 2013).

Botanicals

Baskaran and Narayanasamy (1995) collected the details on the indigenous practices of using botanicals against the rhinoceros beetle in TamilNadu. They observed a practice of mixing sand 250 g with neem seed powder (*Azadirachta indica*) 100 g and placement at the base of leaf sheath after removing the old spathe of coconut. Another method used was the placement of paddy husk in the spathes to prevent the damage by rhinoceros beetle.

Baskaran and Narayanasamy (1995) reported on a farmer practice of sprinkling of extract of *Cannabis* sp. and extract from *Ficus* sp. on the coconut crown to prevent the beetle attack. Similar observations were made by Unnikrishnan (2012).

The incorporation of *Clerodendron infortunatum* at 10 percent w/w basis in the cowdung or manure pits is being recommended to contain the young stages of rhinoceros beetle (Chandrika and Nair (2000); KAU, 2007 and 2011 and Josephrajkumar *et al*., (2012).

Chandrika *et al.,* (2001) reported that application of oil cakes of neem in powder form @ 250 g or *Hydnocarpus wightiana* (marotti cake) mixed with equal volume of sand, thrice a year to the base of the spindle leaf of coconut palm was an effective prophylactic method against rhinoceros beetle and red palm weevil. In laboratory studies, they demonstrated that herbal concentrate of neem 10 per cent, azadiractin 0.50 per cent, annona extract 10.00 per cent and marigold extract 10.00 per cent were effective in killing the grubs, pupae and adults of red palm weevil to the tune of 25.80 to 41.70 per cent.

Ramaraju and Pretheep kumar (2005) explained that a mixture of either neem seed powder + sand (1:2) at 150 g per palm or neem seed kernel powder + sand (1:2) at 150 g applied in the base of the three innermost leaves in the crown effectively controls the pest. These treatments are being recommended by the TNAU Expert system (2013) also.

As a management measure against rhinoceros beetle, application of 250 g neem cake or marotti (*Hydnocarpus wightiana*) cake mixed with equal volume of sand in the innermost two to three leaf axils has to be done twice, i.e., during April-May before the onset of south-west monsoon and during September-October after the south-west monsoon (KAU, 2007 and 2011).

The Cocoa and Coconut Institute (CCI), Papua New Guinea stated that there were several ways to control the spread of the rhinoceros beetle. The beetle could be controlled by using a mixture of neem leaves and sand to repel the beetles from eating the coconut leaves. They said this could be done by mixing neem tree leaves which contain a special chemical compound with sand and having it rubbed in the coconut crown (Port, 2009).

The traditional method of application of a mixture of sand, salt and charcoal on coconut leaf axils to control the rhinoceros beetle was reported to be ineffective by Unnikrishan Nair (2012).

BIOLOGICAL CONTROL

Macrobial control

Vanderplank (1958) reported on the use of assassin bug *Platymeris rhadamanthus* Cerst. against the rhinoceros beetle. The larvae of the Scoliid wasps were observed as external parasites of the rhinoceros beetle grubs. *Scolia oryctophaga* Coq., and *Scolia ruficornis* F. were wasp species introduced into Madagascar, Zanzibar and Samoa, respectively. The results were very variable (Thampan, 1975; Waterhouse and Norris, 1987). *Scolia patricialis* Burm., var. Plebeja Girb., was reported to parasitise *Oryctes* larvae in Malaya by Bryan (1949).

The assassin bug, *Platymeris laevicolis* Distant was reared and released but did not establish as predator in Guam in the 60's (Schreiner 1989).

Predators have been observed feeding on the eggs and early instar larvae

of the rhinoceros beetle. They include *Santalus parallelus* Payk., *Pheropsophus occipitalis* Macleay, *P.lissoderus, Chelisoches morio* (Fab.) and species of Scarites, Harpalus and Agrypnus and non insects like frogs, toads, birds and rats (Antony and Kurian, 1966; Kurian *et al.,* 1983; Nair and Visalakshi, 1999). The Carabid, *Mecodema spinifer* and the Histerid, *Pachylister chinensis* Quensel, are predaceous on *Oryctes* larvae in Samoa. Similarly, certain species on the genus *Leionota* have also been reported to prey upon *Oryctes* larvae in Fiji.

MICROBIAL CONTROL

Fungi

Friederichs (1913) observed the entomogenous fungus, *Metarhizium anisopliae* (Metchnikoff) Sorokin attacking the rhinoceros beetle in Samoa and suggested its use in breeding traps to control the beetle. Later on Bryce (1915) and Hopkins (1927) worked on this fungus. In India, Nirula *et al.,* (1955) and Radha *et al.,* (1956) studied and reported on the activity of the fungus and its possibility as a biological agent.

Methods for mass culture of *M. anisopliae* were developed later by scientists like Mohan and Pillai (1982) and Dangar *et al.,* (1991). The farmyard refuse heaps and cattle dung pits could be inoculated with fungal preparation at 5×10^{11} spores per m^3 to control rhinoceros beetle grubs.

Pillai *et al*., (1993) reported that the pathogen *M. anisopliae* was lethal to the rhinoceros grubs in the breeding places at low temperature and humidity levels.

Nampoothiri, (1999) recommended 80 ml spore suspension containing 10^9 to 10^{11} *M. anisopliae* spores per ml for treating one cubic metre breeding site of the rhinoceros beetle.

In the Philppines, trap boxes with decaying saw dust with 50 to 100 g green muscardine fungus (GMF) at the base, were kept in coconut plantations.

116 boxes trapped 20000 adults and grubs in one year. Saw dust and GMF were replaced once in three months (PCARRD, 2006).

Treating breeding sites of beetles with green muscardine fungus, *Metarhizium anisopliae* @ $5x10^{11}$ spores per m^3 is being recommended against rhinoceros beetle grubs (KAU, 2007 and 2011; Nair *et al.,* 2011 and Josephrajkumar *et al.,* 2012).

Virus

Surveys were carried out to identify the diseases of the rhinoceros beetle in the coconut growing regions of the tropics by workers like Surany (1960) and Huger (1966). A Rhabdionvirus later renamed as baculovirus was discovered infesting the rhinoceros beetle in oil palm estates in Malaysia 1963. The first pilot release of the virus was conducted in Western Samoa in 1967. This baculovirus was reported as a very potent pathogen by Zelazny (1981). Caltagirone (1981) stated that the use of the baculovirus was one of the landmark examples of biocontrol of crop pests.

Under the rhinoceros beetle project in Samoa, Marschall and Loane (1982) utilized the baculovirus for biological control. The application of virus suppressed the beetle population and established itself in the wild beetle population several years after its introduction at levels between 30 to 50 per cent.

Mohan *et al.,* (1989) reported that the beetle population has been substantially reduced in Minicoy, Lakshadweep, India, through the release of baculovirus infected beetles.

In the Philippines, the effect of baculoviruses on suppression of *O. rhinoceros* was studied since the mid-1980s. Introduction of the baculovirus into disease-free islands lowered the pest population density to 10–20 per cent of the pre-release levels, and over 40 per cent of the adult beetles became infected (Zelazny and Alfiler, 1990).

When *oryctes niridivirus* infected adults were released in Kerala, the number of oil palms with central spear damage fell from 71 per cent to 21 per cent (Dhileepan, 1994) and coconut fronds damaged over three years fell from seven per cent to three per cent (Babjan *et al.,* 1995).

The release of 10-15 Baculovirus *oryctes* infected adults per ha is being recommended for biological control of the pest by (KAU, 2007 and 2011). Whereas, Josephrajkumar *et al.,* (2012) stated on the release of *O. rhinoceros* nudivirus infected beetles @ 10 - 12 beetles per ha as part of management strategy against the rhinoceros beetle.

At present the baculovirus is being used for biological control of the beetle in countries like Malaysia, Maldives, Indonesia, Phillippines, Pacific Islands and in the African continent.

Chemical control

Various insecticides were tried for the control of beetle grubs in the breeding places. The pesticides like DDT, DDD, toxaphene, BHC, chlordane, calcium arsenate, lead arsenate, paris green and sodium arsenate were used but some of them were very toxic and posed hazards to cattle, poultry and human beings. The application of 0.01 per cent gamma BHC was found to be effective and became a normal practice (Nirula *et al.,* 1951; Menon and Pandalai, 1958).

In studies on control of rhinoceros beetle with leaf axil filling of sand or clay mixed with different insecticides, it was found that sand mixed with either BHC or chlordane was effective against the pest. In an experiment on using pesticides in breeding places, it was observed that the average attack in coconut palm block close to pits treated with 0.01 per cent BHC was 2.40 per cent whereas it was 12.30 per cent in the control block (Menon, 1956).

Menon and Pandalai (1958) reported that during dry weather, filling of the leaf axils of the central leaves in the crowns with a mixture of sand and five per

cent BHC dust in equal proportions gave protection to the palms from the beetle attack.

Kurian and Pillai (1964) reported that Aldrin 0.01 per cent used for treatment of compost pits was effective against rhinoceros beetle.

After removing the beetle, the hole was filled with a mixture of sand and a suitable insecticide. The same mixture was also plugged into the axils of the leaves of unattacked plants, so that adults would be poisoned when they visited the palms for feeding (Pradhan, 1969).

Insecticides such as 90 per cent lindane granules mixed with saw dust (Mariau, 1967 and 1971) or a mixture of one part gamma benzene hexachloride (50 per cent WP) : nine parts damp saw dust (Nirula, 1955; O'Connor, 1957) could be placed in the axils of the youngest four to five fronds, but this was labour intensive. The pouring of dieldrin into holes drilled at one metre intervals along old oil palm trunks to prevent development of rhinoceros beetle larvae was effective but required trained labour (Mariau and Calvez, 1973).

Toh and Brown (1978) recommended the application of carbofuran at four to six intervals as a prophylactic control measure against coconut rhinoceros beetle in oil palm.

Abad *et al.*, (1982) indicated that in the Phillippines, the leaf axil placement of carbofuran 3 G (0.7 g a.i. per palm) or diazinon 5 G (1.26 g a.i. per palm) or granules at four to six weeks intervals prevented the beetle attack. However, these insecticides were not superior to gamma BHC 6 G (1.39 g a.i. per palm) which was later withdrawn from market.

Ho and Toh (1982) reported on the use of naphthalene balls to control the pest because of its repellent action. These observations were further supported by Gurmit (1987) and Sadakathulla and Ramachandran (1990). Pardede and Utomo (1992) and Jacob (1996) also achieved the desired control up to 45 days using two

balls per palm, based on the results of a two year study. Sushil and Ahmed (2008) also reported that napthalene balls @ four per palm gave excellent control of the beetle.

The three top most leaf axils around the spindle have to be filled with a mixture of BHC five per cent DP or Chlordane five per cent DP and sand in equal proportion by volume or BHC 10 per cent and sand in the proportion of 1:2. Leaf axil filling has to be done thrice in an year in April, September and December as a prophylactic measure against rhinoceros beetle (KAU, 1982).

Treatment with 10 per cent granules of phorate was reported to give protection up to 60 days when applied at five g per palm (Jayaraman, 1985). Pillai *et al.,* (1993) recommended the placement of 10 G phorate in perforated polybags in leaf axils of the palms.

Nair (1989) reported that filling the innermost two to three leaf axils of the palm, at two to three months intervals, with BHC 5 per cent dust plus sand in equal proportion (100 g each per palm) was an effective prophylactic measure against the pest.

Chung *et al.,* (1991) evaluated lambdacyhalothrin, cypermethrin, fenvalerate, monocrotophos and chlorpyriphos both in nursery and fields of oil palm in Malaysia. All were effective up to 11 weeks in controlling the rhinoceros beetle.

Ho (1996) opined that carbofuran granules were not effective at high population levels of coconut rhinoceros beetle in oil palm.

Gurmit (1987) reported that naphthalene balls applied at fortnightly intervals in oil palm gave 95 per cent control of the coconut rhinoceros beetle. However, Chung *et al.,* (1991) and Ho (1996) reported poor control of the pest by this method.

After cleaning, the bore holes have to be filled with a mixture of three g

mancozeb plus one kg sand. Application of 25 g Sevidol 8 G (Lindane plus Carbaryl) mixed with 200 g fine sand into the well around the base of the spindle repelled the beetles (Nair *et al*., 1997).

Hean (2004) reported that a soluble powder of Cartap or Nerestoxin packed in tissue bags of 30 g were placed on the top of the young palms (shorter than 2.5 m). One bag was put into the leaf base around the first unopened leaves, and applied again within 20 to 30 days.

Ramamurthy *et al.,* (2005) recommended that after extraction of beetles, a mixture of sand plus carbaryl 10 per cent dust in equal proportions should be filled in the axils of innermost two to three leaves on the crown twice a year during pre and post monsoon periods.

As a chemical control method against the rhinoceros beetle, Sevidol 8 G 25 g + fine sand 200 g, has to be applied in a year in the two innermost leaf axils of the coconut crown during April - May, September- October and December – January (KAU, 2007 and TNAU Expert system, 2013).

Naphthalene balls 12.0 g (approx. 4 nos.) have to be placed in the innermost two leaf axils and covered with fine sand, once in 45 days to prevent rhinoceros beetle attack (KAU, 2007 and 2011).

Josephrajkumar *et al.,* (2012) recommended the application of chlorpyriphos dust (two to three g) along with sand on the collar region of coconut seedlings to control the rhinoceros beetle.

The systemic granule phorate 10 G five g in perforated sachets has to be placed in the two innermost leaf axils twice a year. After extraction of beetles, filling bore holes with three g mancozeb + one kg sand is being recommended by TNAU Expert system (2013).

Integrated Pest Management (IPM) of the rhinoceros beetle

Nair (1975) stated that effective control of the rhinoceros beetle could be obtained only by integrating the different control measures like cultural, mechanical and chemical.

Zelazny *et al.,* (1985) envisaged an IPM for coconut rhinoceros beetle in the Pacific islands incorporating the different methods of control.

IPM against rhinoceros beetle was advocated by Vidyasagar and Bhatt (1991) and Pillai *et al.* (1993). In later years, the research findings on rhinoceros beetle control have found place in the IPM approaches. The information on a holistic IPM has been given by KAU (2007 and 2011), Nair *et al.,* (2011), Coconut Development Board, (2012), Mohan and Josephrajkumar, (2013) and TNAU Expert system (2013).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Survey was conducted in coconut growers' gardens to study the cultivation practices and constraints in coconut cultivation, assess the extent of infestation of rhinoceros beetle (*Oryctes rhinoceros* L.) in two panchayats each in the coastal and midland physiographic regions of Neyyattinkara taluk in Thiruvananthapuram from April 2012 to May 2012. Field experiments were conducted to evolve management measures using new generation insecticides and botanicals against the rhinoceros beetle. Four farmers' coconut gardens were selected in Chenkal, Perumpazhuthoor, Thirupuram and Kottukal panchayats of Neyyattinkara taluk for the experiments. The trials with nine treatments were conducted from June 2012 to March 2013.

3.1 Survey on coconut cultivation and rhinoceros beetle infestation in Neyyattinkara taluk

A survey was conducted in four panchayats of Neyyattinkara taluk, *viz*., two coastal panchayats, Thirupuram and Kottukal and two midland panchayats, Chenkal and Perumpazhuthoor. Coconut gardens of ten farmers having a minimum of forty palms were surveyed from each panchayat. Ten palms were randomly selected for the survey from each garden. A total of four hundred palms from forty coconut gardens of the four panchayats were marked and observed for the study. Observations were recorded in a proforma prepared for the purpose.

3.1.1. Profile of coconut gardens and crop husbandry practices in Neyyattinkara taluk

The details of the farmers and their coconut gardens, crop husbandry practices including plant protection practices followed and constraints in adoption of recommended practices in coconut were recorded and analysed.

3.1.2. Infestation by rhinoceros beetle on coconut

A total of four hundred palms were observed in 40 farmers' coconut gardens. The following observations were taken and recorded from the selected palms in the four panchayats during the survey. The methodology adopted by Ramachandran (1961) in assessing rhinoceros beetle infestation on coconut palms was used for the study with suitable modifications.

Palms showing infestation by rhinoceros beetle

The number of palms exhibiting infestation by rhinoceros beetle out of the total number of the coconut palms observed were recorded from each farmer's plot. The percentage of palms showing infestation by rhinoceros beetle was worked out and statistically analysed.

Fresh infestation by rhinoceros beetle on palms

Fresh chewed up frass in the crown was taken as an indication of fresh infestation. The number of palms exhibiting fresh damage out of the total was observed and percentage of palms showing fresh infestation was worked out. The data was subjected to statistical analysis.

Leaves (fronds) infested by rhinoceros beetle

The number of leaves infested by rhinoceros beetle and total number of leaves in the selected coconut palms were recorded. The percentage of leaves infested was worked out and statistically analysed.

Central spindles infested by rhinoceros beetle

The number of palms showing central spindle damage by rhinoceros beetle out of the total number of central spindles in the selected palms were observed. The percentage of central spindles infested by rhinoceros beetle was statistically analysed.

Spathes infested by rhinoceros beetle

The number of spathes freshly infested by rhinoceros beetle in the selected coconut palms were recorded. The number of spathes exhibiting damage out of the total was observed. The percentage of spathes showing infestation was worked out and statistically analysed.

Spathes dried due to rhinoceros beetle attack

The numbers of palms exhibiting dried spathes due to rhinoceros beetle infestation out of the total number of spathes were observed in the selected palms. The percentage of dried spathes due to rhinoceros beetle attack was worked out and statistically analysed.

3.1.3. Infestation by other pests and diseases in coconut

The number of palms exhibiting infestation by the coreid bug (*Paradasynus rostratus* Dist.), eriophyid mite (*Aceria [Eriophyes] guerreronis* Keifer), mealy bugs (*Pseudococcus longipinus* Targ. and *Pseudococcus cocotis* Mask.) and red palm weevil (*Rhynchophorus ferrugineus* F.) were observed in the selected palms. The percentage of palms infested by the above pests was worked out. Similarly the number of palms infected by bud rot and leaf rot were also observed in the selected palms. The percentage of palms exhibiting the symptoms of bud rot and leaf rot were worked out.

3.1.4 Rhinoceros beetle infestation on other crops

The other crops observed in coconut gardens *viz.*, banana, arecanut, pineapple and ornamental palms were observed for infestation by rhinoceros beetle.

3.1.5 Correlation between rhinoceros beetle damage and weather parameters in Perumpazhuthoor and Thirupuram panchayats

The weather parameters *viz.*, maximum, minimum temperature, relative humidity morning, relative humidity afternoon and number of rainy days (March 2012 to July 2012) prevailing in the region before the survey were recorded. Correlations were worked out between the mean of the weather parameters of the preceeding 20 days on percentage of leaves, central spindles and spathes infested due to rhinoceros beetle in two panchayats viz., Perumpazhuthoor (midland) and Thirupuram (coastal).

3.1.6 Monitoring of rhinoceros beetle using aggregation pheromone traps (rhinolure)

An aggregation pheromone – rhinolure supplied by M/s Pest Control India Private Limited, Bengaluru was used to monitor rhinoceros beetle. The aggregation pheromone (rhinolure) was placed inside a collapsible bucket trap (named as Coco Trap by the firm).

The Coco Trap was installed at about two metres height from ground level in the vicinity of the selected coconut garden (plate.1). The trap was readied for use by pouring two litres of water along with coconut coir as food bait and half a tea spoon of detergent as wetting agent to kill the trapped adults. RB-Lure was inserted in the slot provided on the undersurface of the lid of the Coco - Trap.

Four aggregation pheromone traps (rhinolure) were placed in four coconut gardens (four panchayats) representing *viz*., two coastal regions, Thirupuram and Kottukal and two mid land regions, Chenkal and Perumpazhuthoor.

The traps were installed from May 2012 to July 2012. The total number of adults collected in pheromone traps were recorded at fortnightly intervals for period of three months (six fortnights). The numbers of male and female adults

Plate.1. Monitoring of rhinoceros beetle using aggregation pheromone trap (rhinolure).

trapped per fortnight in the four locations were worked out and subjected to statistical analysis.

3.1.7 Correlation between numbers of rhinoceros beetles (collected in pheromone traps) with weather parameters

The details of weather parameters *viz.,* maximum, minimum temperature, relative humidity morning and afternoon and number of rainy days were collected from May 2012 to July 2012. The average of weather parameters of the preceeding 20 days before taking count of rhinoceros beetle adults in the pheromone trap was worked out. The same observations were recorded during the ensuing five fortnights. The average of weather parameters of six fortnights from May 2012 to July 2012 was worked out.

Correlations were worked out between the average number of rhinoceros beetle adults trapped per fortnight and the average weather parameters of the preceeding 20 days.

3.1.8 Constraints in adoption of recommended practices in coconut

Ten constraints perceived by all the forty farmers in adoption of recommended practices for cultivation of coconut in each panchayat were listed. Farmers were asked to rank the constraints from most important to least important in each panchayat. The data obtained was tabulated and subjected to Kendall's coefficient of concordance analysis. Here the agreement among the farmers in each panchayat as they ranked the ten constraints was calculated. The data on constraints perceived by all the farmers in the four panchayats was pooled and statistically analysed.

3.2 Field evaluation of new generation insecticides and botanicals to control the rhinoceros beetle in coconut

Field experiments to control the rhinoceros beetle were conducted in Neyyattinkara taluk. One coconut garden was selected from each of the four

panchayats surveyed (plates. 2. 3. 4. 5. showing locations at Chenkal, Perumpazhuthoor, Thirupuram and Kottukal respectively). In each garden (location), the experiment was conducted in young palms age 10 to 12 years (less than fifteen years of age).

Experimental design

Crop : Coconut

Variety : West Coast Tall

Locations : Chenkal, Perumpazhuthoor, Thirupuram and Kottukal

Design : RBD

Treatments : 9

Replications : 5 (One palm per replication)

The treatments were:-

T1 – Cc + Cartap hydrochloride (Fast) 4 G 25g + sand 200g leaf axil filling.

T2 – Cc + Carbosulfan (Sheriff) 6 G 25g + sand 200g leaf axil filling.

T3 – Cc + Fenvalerate (Fenval) 0.4 DP 50g + sand 200g leaf axil filling.

T4 – Cc + Chlorpyriphos (Hi-tech) 1.5DP 50g + sand 200g leaf axil filling.

T5 – Cc + Fipronil (Regent) 0.3 G 100g + sand 200g leaf axil filling.

T6 – Cc + Crushed neem seed kernel 100g + sand 200g leaf axil filling.

T7 – Cc + Chopped tobacco leaves 100g + sand 200g leaf axil filling.

T8 – Farmer’s practice (only crown cleaning)

T9 – Untreated

Field experiments - Location

Plate. 2. Chenkal.

Plate. 3. Perumpazuthoor

Plate. 4. Kottukal.

Plate. 5. Thirupuram

Crown cleaning (Cc) - Common for T1 to T7 treatments.

The first application was given during the month of May 2012, second month of September 2012 and the third application in the month of January 2013.

Preparation and application of chemical and botanical treatments

Cartap hydrochloride (Fast) 4 G

Cartap hydrochloride (Fast) 4 G manufactured by Tropical Agro Chemicals Limited was used for the experiment. 25 g of Fast was mixed with 200 g of sand and taken in a bottle. After cleaning the crown of the treatment palm, the mixture was applied in the innermost three leaf axils.

Carbosulfan (Sheriff) 6 G

Carbosulfan (Sheriff) 6 G manufactured by FMC India Private Limited was used for the experiment. 25 g of Sheriff was mixed with 200 g of sand and taken in a bottle. After cleaning the crown of treatment palm, the mixture was applied in the innermost three leaf axils.

Fenvalerate (Fenval) 0.4 DP

Fenvalerate (Fenval) 0.4 DP manufactured by ISAGRO Asia Agro Chemicals Private Limited was used for the experiment. 50 g of Fenval was mixed with 200 g of sand and taken in a bottle. After cleaning the crown of treatment palm, the mixture was applied in the innermost three leaf axils.

Chlorpyriphos (Hi-tech) 1.5 DP

Chlorpyriphos (Hi-tech) 1.5 DP manufactured by Jairaks India Limited was used. 50 g of Hi-tech was mixed with 200 g of sand and taken in a bottle. After cleaning the crown of treatment palm, the mixture was applied into the innermost three leaf axils.

Fipronil (Regent) 0.3 G

Fipronil (Regent) 0.3G manufactured by Syngenta India Private Limited was used. 50 g of Regent was mixed with 200 g of sand and taken in a bottle. After cleaning the crown of treatment palm, the mixture was applied in the innermost three leaf axils.

Neem seed kernel

100 g of good quality neem seed kernels were crushed and mixed with 200 g of sand and used for leaf axil filling as explained above.

Tobacco leaves

100 g of tobacco leaves were chopped into very small pieces and mixed with 200 g sand and used for leaf axil filling as explained earlier.

The number of rhinoceros beetles and extent of damage on palms were recorded from treated palms 15, 30 and 45 days after application of each treatment in May 2012, September 2012, and January 2013. The observations were recorded in the following manner.

Number of rhinoceros beetles in coconut palms

The number of rhinoceros beetles present in each treated palm was recorded in the four locations. The pooled mean number of rhinoceros beetles per five palms in the four locations was worked out and subjected to statistical analysis.

Fresh damage to crowns by rhinoceros beetle

The crown of each treated palm was observed and fresh damage was recorded in the four locations. The pooled mean of freshly damaged crowns per

five palms of the four locations was worked out and data was statistically analysed.

Fresh infestation on spindles by rhinoceros beetle

The spindle of each treated palm was observed and fresh damage was recorded. The pooled mean (of four locations) of fresh damage to spindles per five palms was worked out and subjected to statistical analysis.

Fresh infestation on spathes by rhinoceros beetle on coconut palms

The fresh spathe of each treated palm was observed and fresh damage if any was recorded. The pooled mean percentage of freshly damaged spathes per five palms in the four locations was worked out.

Number of emerged bunches exhibiting infestation by rhinoceros beetle six weeks after each application of treatments

The number of emerged bunches exhibiting infestation by rhinoceros beetle was recorded six weeks after application of treatments. The pooled mean of emerged bunches exhibiting infestation by rhinoceros beetle per five palms in the four experiments was worked out and statistically analysed.

Number of emerged bunches uninfested by rhinoceros beetle six weeks after each application of treatments

The number of emerged bunches uninfested by rhinoceros beetle was recorded six weeks after each application of treatments. The pooled mean of emerged bunches uninfested by rhinoceros beetle per five palms in the four experiments was worked out and statistically analysed.

Statistical analysis

Survey of the mean values and percentage were worked out and analysed. Field experiment analysis as per RBD was carried out with suitable transformations wherever necessary.

Kendall's coefficient of concordance was used for the study of the ranking of the constraints of the respondents. Coefficients were used for studying the relationship of meteorological data with crop damage due to the rhinoceros beetle.

RESULTS

4. RESULTS

4.1 Survey on coconut cultivation in Neyyattinkara taluk

The survey covered a total of 40 farmers. Ten farmers' gardens were surveyed from each panchayat i.e., Chenkal, Perumpazuthoor, Thirupuram and Kottukal of Neyyattinkara taluk.

4.1.1 Profile of coconut gardens and crop husbandry practices in Neyyattinkara taluk

The details of the farmers, their coconut gardens and crop husbandry practices including plant protection followed are given in table 1.

Fifty five per cent of the farmers were above the age group of fifty years. 32.50, 17.50 and 27.50 per cent of the farmers had completed Secondary School Leaving Certificate (SSLC), SSLC plus ITI and pre - degree courses respectively. 50 per cent of the farmers had a land area between 50 and 100 cents under coconut. 45.00 per cent and 30.00 per cent of farmers have grown coconut palms in an area of 50 and 100 cents and less than 50 cents, respectively. 72.50 per cent of farmers have grown coconut palms in garden land and the rest in wetland.

The survey revealed that 87.50 per cent of the palms surveyed belonged to the West Coast Tall (WCT) and 7.50 per cent were of the 'Orange – gowligathra' variety. Only 5.00 per cent of palms were hybrids (Tall x Dwarf-TxD). Fifty five per cent of the coconut palms were above 40 years old, 32.50 per cent and 12.50 per cent palms were in the age group of 21 to 40 years and less than 20 years, respectively. 82.50 per cent of the farmer's coconut gardens yielded less than 40 nuts per palm per year. 12.50 per cent of farmers' coconut gardens obtained an average yield between 40 to 60 nuts per palm per year, whereas only five per cent of gardens gave more than 60 nuts per palm per year. The recommended spacing of 7.5m x 7.5m was followed only by 20 per cent of the farmers. The survey showed that only 12.50 per cent of the farmer's

coconut gardens were irrigated. With regard to the use of organic manures, majority of the farmers (62.50 per cent) used cow dung manure which was the most preferred. Cow dung along with ash was used by 15.00 per cent of the farmers. Only 20.00 per cent of the farmers applied recommended doses of fertilizers. 35.00 per cent of the farmers applied less than the recommended dose of fertilizers. 45.00 per cent of the farmers surveyed did not apply any chemical fertilizers.

Among the cultural plant protection measures undertaken against the rhinoceros beetle. 32.50 per cent of farmers practised field sanitation to prevent breeding sites of the beetles whereas 27.50 per cent of the farmers practised crown cleaning. Among the mechanical methods, hooking out the beetles using beetle hook was practised by 10.00 per cent of the farmers. Application of neem cake mixed with sand in leaf axils was undertaken by 20.00 per cent of the farmers. 10.00 per cent of the farmers placed naphthalene balls and covered the same with the sand in the inner most two leaf axils. None of the farmers applied pesticide dust with sand or any other chemical pesticides to untreated the rhinoceros beetle.

4.1.2. Infestation by rhinoceros beetle on coconut

The results of analysis on the infestation by rhinoceros beetle on coconut palms in farmers' gardens in different panchayats are presented in table 2.

The maximum percentage of infestation (83.00) was recorded in Perumpazhuthoor panchayat which was significantly higher compared to the infestation in Kottukal panchayat. The percentage of palms infested ranged from 72.00 to 83.00 in the different panchayats. The lowest percentage of infested palms (72.00) was recorded in Kottukal panchayat but it was statistically on par with Thirupuram and Chenkal panchayats wherein the palms were infested to levels of 72.00 and 78.00 respectively.

The percentage of fresh infestation ranged from 23.64 to 27.27 in the different panchayats and was statistically not significant. The lowest percentage of

Table 1. Profile of coconut gardens and crop husbandry practices in Neyyattinkara taluk.

Sl. No.	Category	Frequency	Percentage
a	**Age group of farmers**		
1	21-30 years	2	5.00
2	31-40 years	7	17.50
3	41-50 years	9	22.50
4	>50 years	22	55.00
	Total	**40**	**100**
b	**Education**		
1	Upto 10^{th} standard	2	5.00
2	SSLC	13	32.5
3	SSLC+ITI	7	17.5
4	Pre degree	11	27.5
5	Degree	7	17.5
	Total	**40**	**100**
c	**Size of holding (cents)**		
1	< 50	7	17.50
2	50-100	20	50.00
3	>100	13	32.50
	Total	**40**	**100**
d	**Area under coconut palm (cents)**		
1	< 50	12	30.00
2	50-100	18	45.00
3	>100	10	25.00
	Total	**40**	**100**
e	**Type of land**		
1	Wet land	11	27.50
2	Garden land	29	72.50
	Total	**40**	**100**
f	**Coconut variety used**		
1	West Coast Tall – WCT (Local)	35	87.50
2	Orange (gowligathra)	3	7.50
3	Tall x Dwarf – TxD (hybrid)	2	5.00
	Total	**40**	**100**
g	**Age of palms**		
1	>40 years	22	55.00
2	21-40 years	13	32.50
3	<20 years	5	12.50
	Total	**40**	**100**
H	**Yield (nuts/palm/year) in farmers' field**		
1	<40	33	82.50

2	40-60			5	12.50
3	>60			2	5.00
	Total			**40**	**100**
i	**Spacing adopted by farmers**				
1	Recommended spacing (7.5 x 7.5m)			8	20.00
2	Not recommended			32	80.00
	Total			**40**	**100**
j	**Irrigation**				
1	Irrigated			5	12.50
2	Not irrigated			35	87.50
	Total			**40**	**100**
k	**Manures used**				
1	Cow dung (i)			25	62.50
2	Compost (ii)			1	2.50
3	Green leaves (iii)			-	-
4	Neem cake (iv)			-	-
5	Poultry manure (v)			-	-
6	Ash (vi)			-	-
7	Salt (vii)			1	2.50
8	i + iv			3	7.50
9	i + vi			6	15.00
10	i + ii + v			1	2.50
11	i + vii			1	2.50
12	i + iii			1	2.50
13	i + vi + vii			1	2.50
	Total			**40**	**100**
l	**Fertilizers used**	**Recommended dose**	**Lower than recommended**	**Not using fertilizers**	**No. of farmers**
				18	18
1	Urea	-	2	-	2
2	MOP	-	1	-	1
3	Factomphos	-	2	-	2
4	Mixture	1	1	-	2
5	Complexes	1	2	-	3
6	MgSo4	-	1	-	1
7	1+2+3	1	1	-	2
8	1+3+4	1	2	-	3
9	3+4+5	2	2	-	4
10	3+4	1	-	-	1
11	1+3+4+5	1	-	-	1
	Total	**8**	**14**	**18**	**40**
	Percentage	**20.00**	**35.00**	**45.00**	**100**

Table (cont.....)

M	**Plant protection measures adopted against rhinoceros beetle.**			
	Methods		**Frequency**	**Percentage**
1.	Cultural	a) Provide field sanitation to prevent breeding sites	13	32.50
		b) Crown cleaning	11	27.50
2.	Mechanical	a) Hook out the beetles from the attacked palms by using beetle hook	4	10.00
		b) Traps	Nil	_
3.	Biological	a) *Baculovirus oryctes*	Nil	_
		b*) Metarrhizium anisopliae*	Nil	_
4.	Organic (Botanicals)	a) Neem cake application + sand in leaf axils	8	20.00
		b) *Clerodendron infortunatum* in pits	Nil	_
5.	Chemicals	a) Naphthalene balls in the inner most 2 leaf axils and covered with fine sand	4	10.00
		b) Pesticide dust + sand in leaf axils	Nil	_
		c) Any other chemical application	Nil	_
	Total number of farmers		**40**	**100**

fresh infestation on palms (23.64) was recorded in Perumpazhuthoor panchayat followed by Thirupuram (26.27) and Chenkal (26.37). The highest percentage of fresh infestation was recorded in Kottukal panchayat (27.27) (Table 2).

The maximum percentage of leaves infested (56.41) was recorded at Perumpazhuthoor panchayat which was significantly higher compared to the infestation in Kottukal panchayat (46.71) (Table 2).The percentage of leaves infested ranged from 35.86 to 56.51 in the different panchayats. The lowest percentage of leaves infested was recorded in Kottukal panchayat (35.86) but it was statistically on par with Thirupuram and Chenkal panchayats with 42.34 and 46.71 per cent leaf damage, respectively.

The percentage of central spindles infested ranged from 27.00 to 42.00 in the different panchayats. The lowest percentage of central spindles infested by rhinoceros beetle attack was found in Kottukal panchayat (27.00) which was statistically on par with Chenkal panchayat. 42.00 per cent of the central spindles were infested by rhinoceros beetle attack in Perumpazhuthoor and Thirupuram panchayats. This was significantly higher compared to the central spindle damage at Kottukal and Chenkal (Table 2).

The percentage of fresh spathes infested by rhinoceros beetle ranged from 13.07 to 15.67 in the different panchayats. The percentage of fresh spathes infested by rhinoceros beetle was found to be the lowest in Chenkal (13.07) followed by Thirupuram (13.75).The maximum percentage of fresh spathes infested due to rhinoceros beetle on coconut palms was in Kottukal panchayat (15.61) closely followed by Perumpazhuthoor panchayat (15.29). They were statistically on par (Table 2).

The percentage of dried spathes due to rhinoceros attack was observed and ranged from 7.07 to 8.85 (Table 2). The lowest percentage of dried spathes (7.07) due to rhinoceros beetle attack was recorded in Thirupuram whereas the next highest percentage of spathes dried was recorded in Kottukal and Chenkal

Table 2. Infestation by rhinoceros beetle on coconut in farmers' gardens.

Panchayats	Palms showing infestation %	Leaves Infested %	Fresh infestation on palms %	Central spindles infested %	Fresh spathes infested %	Spathes dried due to Infestation %
Chenkal	78.00	46.71	26.37	31.00	13.07	7.16
Perumpazhuthoor	83.00	56.41	23.64	42.00	15.29	8.85
Thirupuram	77.00	42.34	26.27	42.00	13.75	7.07
Kottukal	72.00	35.86	27.27	27.00	15.61	7.10
C.D (0.05)	7.31	11.25	N.S	9.59	N.S	N.S

N.S – Non Significant

(7.16). The highest percentage of dried spathes due to the pest was observed in Perumpazhuthoor (8.85).

4.1.3 Infestation by other pests and diseases on coconut.

The results of the survey on infestation by pests other than rhinoceros beetle and diseases in the four panchayats of Neyyattinkara taluk are presented in (Table 3).

Coreid bug

The palms infested by coreid bug ranged from 14.00 to 56.00 per cent in the four panchayats. The lowest percentage damage was observed in Chenkal and the highest in Perumpazhuthoor. Altogether, among the four hundred palms surveyed, coconuts in 33.25 per cent of the palms were infested in varying degrees.

Eriophyid mite.

The percentage of palms infested by eriophyid mite ranged from 25.00 to 46.00 per cent in the four panchayats. The maximum percentage was observed in Chenkal followed by Thirupuram. The percentage of palms infested was higher in Kottukal and Perumpazhuthoor panchayat. Out of the total number of four hundred palms surveyed, 35.25 per cent of the palms were bearing mite infested nuts (Table 3).

Mealy bugs

The percentage of palms infested by mealy bugs ranged from 4.00 to 22.00 in the four panchayats. The infestation was comparatively lower in Kottukal, Thirupuram and Chenkal (4.00 to 7.00 per cent) whereas it was to the tune of 22.00 per cent in Perumpazhuthoor. Over all, ten per cent of palms surveyed were infested by mealy bugs (Table 3).

Table 3. Percentage of palms infested by other pests and diseases in Neyyattinkara taluk.

(out of 400 palms)

Panchayats	Coreid bug	Mite	Mealy bug	Red palm weevil	Bud rot	Leaf rot
Chenkal	**14**	**25**	**7**	**-**	**11**	**26**
Perumpazhuthoor	**56**	**46**	**22**	**-**	**10**	**33**
Thirupuram	**33**	**27**	**7**	**1**	**19**	**48**
Kottukal	**32**	**43**	**4**	**1**	**06**	**19**
Total no. of palms infested	**135**	**141**	**40**	**2**	**46**	**126**
Percentage of palms infested	**33.25**	**35.25**	**10.00**	**0.50**	**11.50**	**31.50**

Red palm weevil

Bore holes and exudations due to red palm weevil infestation was observed only in two palms out of the four hundred surveyed. Only one palm each in Thirupuram and Kottukal were infested. On the whole, the percentage of palms infested by red palm weevil was 0.50 (Table 3).

Bud rot

The percentage of palms exhibiting but rot symptoms ranged from 6.00 to 19.00 in the four panchayats. Kottukal recorded the lowest 6.00 per cent whereas the highest (19.00) was obtained in Thirupuram panchayat. Out of the four hundred palms surveyed, 11.50 per cent were infected by bud rot (Table 3).

Leaf rot

The percentage of palms affected by leaf rot ranged from 19.00 to 48.00 in the four panchayats. The lowest percentage of infected palms was obtained in Kottukal (19.00) and the highest in Thirupuram (48.00). Among the four hundred palms 31.50 per cent of the palms exhibited leaf rot symptoms (Table 3).

4.1.4. Rhinoceros beetle infestation on other crops.

The incidence of rhinoceros beetle was nil in banana, arecanut, pineapple, ornamental palms and other crops in the farmers' coconut gardens of the four panchayats (Table 4).

Table 4. Damage to other crops by rhinoceros beetle in farmers' gardens.

Sl. No.	Crops	Percentage damage
1	Banana	**0.00**
2	Arecanut	**0.00**
3	Pineapple	**0.00**
4	Ornamental palms	**0.00**
5	Other crops	**0.00**

4.1.5 Correlation between rhinoceros beetle damage and weather parameters in Perumpazhuthoor panchayat (midland) and Thirupuram panchayat (coastal).

Perumpazhuthoor panchayat

The results of the correlation studies between extent of damage caused by the rhinoceros beetle and weather parameters are presented in table 5.

Correlation between percentage of leaves infested by rhinoceros beetle and weather parameters.

The percentage of leaves infested by rhinoceros beetle was negatively correlated with maximum temperature and positively correlated with minimum temperature. The percentage of leaves infested by rhinoceros beetle had negative correlation with relative humidity (morning and afternoon). The percentage of leaves infested by rhinoceros beetle was positively correlated with number of rainy days but not significant (Table 5).

Correlation between percentage of central spindles infested by rhinoceros beetle and weather parameters.

The central spindles infested by rhinoceros beetle was negatively correlated with maximum temperature and positively correlated (0.394) with minimum temperature. It was positively correlated (0.051 and 0.154) with relative humidity in the morning and afternoon. The percentage of central spindles infested by rhinoceros beetle had positive correlation with number of rainy days but not significant (Table 5).

Correlation between percentage of spathes infested by rhinoceros beetle and weather parameters.

The percentage of spathes infested by rhinoceros beetle was negatively correlated with maximum temperature. It had positive correlation with minimum

Table 5. Correlation coefficient between rhinoceros beetle damage and weather parameters in Perumpazhuthoor panchayat (midland).

	Maximum Temp.(°C)	Minimum Temp.(°C)	R.H.Morning (%)	R.H.Afternoon (%)	Number of rainy days
Y_1	-0.035	0.099	-0.071	-0.093	0.406
Y_2	-0.219	0.394	0.051	0.154	0.157
Y_3	-0.279	0.422	0.349	0.345	0.143

Y_1 – percentage of leaves infested by rhinoceros beetle.

Y_2- percentage of central spindles infested by rhinoceros beetle.

Y_3 - percentage of spathes infested by rhinoceros beetle.

(No significant correlation at 5% level)

temperature. The percentage of spathes infested was positively correlated with both relative humidity in the morning as well as afternoon. The percentage of spathes infested was positively correlated with number of rainy days but not significant (Table 5).

Thirupuram panchayat

The relationship between extent of damage caused by the rhinoceros beetle and weather parameters are presented in table 6.

Correlation between percentage of leaves infested by rhinoceros beetle and weather parameters.

The percentage of leaves infested by rhinoceros beetle was negatively correlated with maximum temperature and positively correlated (0.072) with minimum temperature. The percentage of leaves infested by rhinoceros beetle had negative correlation with relative humidity in the morning and positive correlation with relative humidity afternoon. It had positive correlation with number of rainy days but not significant (Table 6).

Correlation between percentage of central spindles infested by rhinoceros beetle and weather parameters.

The percentage of central spindles infested by rhinoceros beetle was positively correlated with maximum and minimum temperature. It had a negative correlation with relative humidity (morning and afternoon). The percentage of central spindles infested by rhinoceros beetle had positive correlation with the number of rainy days but not significant (Table 6).

Correlation between percentage of spathes infested by rhinoceros beetle and weather parameters.

The percentage of spathes infested by rhinoceros had negative correlation with maximum temperature but was positively correlated with minimum

Table 6. Correlation coefficient between rhinoceros beetle damage and weather parameters in Thirupuram panchayat (coastal).

	Maximum Temp.(°C)	Minimum Temp.(°C)	R.H. Morning (%)	R.H. Afternoon (%)	Number of rainy days
Y_1	-0.128	0.072	-0.410	0.054	0.431
Y_2	0.138	0.522	-0.354	-0.287	0.189
Y_3	-0.278	0.408	-0.385	-0.035	0.519

Y_1 - percentage of leaves infested by rhinoceros beetle.

Y_2- percentage of central spindle infested by rhinoceros beetle.

Y_3 - percentage of spathes infested by rhinoceros beetle.

(No significant correlation at 5% level)

temperature. The relative humidity in the morning and relative humidity in the afternoon had negative correlation with percentage of spathes damaged. There was positive correlation between number of rainy days and percentage of spathes infested by rhinoceros beetle (Table 6).

4.1.6. Monitoring of rhinoceros beetle using aggregation pheromone traps (rhinolure).

The results of the statistical analysis on the average number of rhinoceros beetle adults caught per pheromone trap at fortnightly intervals are presented in table 7.

The number of rhinoceros beetle males collected in the pheromone traps ranged from 6.33 to 7.00 in the four panchayats. The male rhinoceros beetle adults caught per pheromone trap was found to be the highest at Thirupuram (7.00), followed by Perumpazhuthoor (6.66) and Kottukal (6.50). The lowest number of rhinoceros beetle adults caught per pheromone trap was 6.33 in Chenkal panchayat.

The average number of rhinoceros beetle females caught per trap per fortnight ranged from 5.66 to 6.00 in the four panchayats and was statistically on par. The average number of female rhinoceros beetle adults that were caught was found to be highest in Perumpazhuthoor and Thirupuram (6.00) followed by Kottukal panchayat at an average of 5.83. The lowest population of rhinoceros beetle caught per pheromone trap at fortnightly intervals was 5.66 in Chenkal. The number of beetles trapped did not differ significantly among the panchayats.

The total catch of rhinoceros beetles per trap per fortnight ranged from 11.99 to 13.00 in the different panchayats. The number of rhinoceros beetles caught at fortnightly intervals in aggregation pheromone trap installed in Thirupuram panchayat was the highest (13.00) followed by Perumpazhuthoor 12.66 and Kottukal panchayat 12.33. The lowest number of adults caught in

Table 7. Average number of rhinoceros beetles collected in aggregation pheromone traps at fortnightly intervals (May 2012 – July 2012).

Panchayats	Male	Percentage of total	Female	Percentage of total	Total
Chenkal	6.33	52.80	5.66	47.20	11.99
Perumpazhuthoor	6.66	52.60	6.00	47.40	12.66
Thirupuram	7.00	53.85	6.00	46.15	13.00
Kottukal	6.50	52.72	5.83	47.28	12.33
C.D (0.05)	N.S	-	N.S	-	N.S

N.S – Non Significant

pheromone trap was Chenkal (11.99). The beetle catch was statistically on par among the panchayats (Table 7).

The percentage of males caught out of the total ranged from 52.60 to 53.85 in the different panchayats. The percentage of females trapped out of the total ranged from 46.15 to 47.40. This indicated that, slightly higher population of males were attracted to pheromone traps compared to the females.

4.1.7. Correlation between number of rhinoceros beetles collected in pheromone traps at fortnightly intervals and weather parameters.

The results of the correlation studies between number of rhinoceros beetles collected in the pheromone traps at fortnightly intervals are presented in table 8.

Chenkal panchayat

The number of rhinoceros beetles had a positive correlation with maximum temperature and minimum temperature. The number of rhinoceros beetles had significant negative correlation with relative humidity morning (-0.866) and relative humidity afternoon (-0.848). The number of rhinoceros beetles caught at fortnightly intervals was positively correlated with the number of rainy days.

Perumpazhuthoor panchayat

The number of rhinoceros beetles collected in pheromone traps at fortnightly intervals had no significant correlation with the weather parameters. There was positive correlation between number of rhinoceros beetles and maximum and minimum temperature. The number of rhinoceros beetles had negative correlation with relative humidity (morning and afternoon). The number of rhinoceros beetles was positively correlated with the number of rainy days (Table 8).

Table 8. Correlation between number of rhinoceros beetles collected in pheromone traps at fortnightly intervals and weather parameters. (May 2012- July 2012)

Panchayats	Maximum Temp. (°C)	Minimum Temp. (°C)	R.H. Morning (%)	R.H. Afternoon (%)	Number of rainy days
Chenkal	0.740	0.639	-0.866*	-0.848*	0.084
Perumpazhuthoor	0.683	0.492	-0.708	-0.716	0.503
Thirupuram	0.630	0.401	-0.837*	-0.809	0.014
Kottukal	0.712	0.611	-0.766	-0.696	0.577

*** significant correlation at 0.05% level**

Thirupuram panchayat

There was positive correlation between the number of rhinoceros beetles collected in pheromone traps at fortnightly intervals with maximum and minimum temperature but it was not significant. A significant negative correlation was obtained between number of rhinoceros beetle adults collected and relative humidity morning and negative correlation with relative humidity afternoon. The catch per fortnight had positive correlation with number of rainy days (Table 8).

Kottukal panchayat

The number of rhinoceros beetle adults trapped was positively correlated with maximum and minimum temperature. The number of rhinoceros beetle adults trapped was negatively correlated with both relative humidity in the morning and afternoon. The fortnightly catch of rhinoceros beetle was positively correlated with the number of rainy days (Table 8).

4.1.8. Constraints in adoption of recommended practices in coconut.

The constraints perceived in adoption of recommended practices in coconut cultivation in the four panchayats was recorded. The association among the respondents in their rankings was studied by Kendall's coefficient concordance. The results obtained in the four panchayats are presented in table 9.

Perumpazhuthoor panchayat

The most important constraint in adoption of recommended practices in coconut was high cost of labour (average rank 1.2), followed by low cost of produce (3.4), lack of irrigation facilities (4.7) and uneconomical holding size (4.7). The other constraints in the order of lesser importance were lack of awareness on current dose of chemicals and fertilizers, high cost of plant protection chemicals, lack of proper guidance and non availability of plant protection chemicals with average rank of 4.8, 6.0, 6.0, and 7.1 respectively. The

second least important constraint was lack of drainage (7.7) whereas the non availability of skilled labour was the least important constraint with an average rank of 9.4. The Kendall's co-efficient of concordance was 0.5791 and was significant. This indicated an agreement among the farmers on their ranking of the constraint.

Chenkal panchayat

The important constraint identified in adoption of recommended practices in coconut were high cost of labour (average rank 1.1) followed by low cost of produce (3.1), lack of proper guidance (3.6) and uneconomical holding size (4.1). The other constraints in the sequence of less importance were non availability of skilled labours, lack of irrigation facilities, high cost of plant protection chemicals, non availability of plant protection chemicals with average rank of 5.2, 6.8, 6.9 and 7.0 respectively. The second least important constraint was lack of drainage (8.6). The least important constraint was lack of awareness on the current dose of chemicals and fertilizers with an average rank of 8.6. The Kendall's co-efficient of concordance was 0.6676 and was significant. This indicated that the farmers concurred on the ranking of the constraints in cultivation of coconut (Table 9).

Thirupuram panchayat

The important constraints in adoption of recommended practices by the farmers in coconut was high cost of labour (average rank 1.8), followed by lack of irrigation facilities (3.3), low cost of produce (3.4) and high cost of plant protection chemicals (5.0). The other constraints being in the order of less importance were non availability of plant protection chemicals (5.3), lack of proper guidance (6.1), not aware of current dose of chemicals and fertilizers (7.3), and lack of drainage (7.4). The least important constraint was uneconomical holding size (7.7) and non availability of skilled labour (7.7). The Kendall's co-

Table 9. Average ranking of constraints in adoption of recommended practices in cultivation of coconut.

Sl. No.	Constraints	Perumpazhuthoor	Chenkal	Thirupuram	Kottukal	Mean
1	Non availability of plant protection chemicals	7.1	7.0	5.3	7.1	6.62
2	High cost of plant protection chemicals	6.0	6.9	5.0	5.5	5.85
3	Lack of irrigation facilities	4.7	6.8	3.3	8.9	5.92
4	Lack of drainage	7.7	8.6	7.4	7.9	7.90
5	High cost of labour	1.2	1.1	1.8	1.2	1.32
6	Uneconomical holding size	4.7	4.1	7.7	3.3	4.95
7	Lack of proper guidance	6.0	3.6	6.1	6.1	5.45
8	Not aware of current dose of chemicals and fertilizers	4.8	8.6	7.3	3.3	6.00
9	Non availability of skilled labour	9.4	5.2	7.7	7.0	7.32
10	Cost of produce is low	3.4	3.1	3.4	4.5	3.60
	Kendall's coefficient of concordance	0.5791*	0.6676*	0.4863*	0.6261*	-

Kendall's coefficient of concordance for ranks given by respondents.

(*significant at 5% level)

efficient of concordance was 0.4863 and was significant. This indicated an agreement among the farmers on their ranking of the constraints.

Kottukal panchayat

The most important constraint identified in adoption of recommended practices in coconut was high cost of labour (average rank 1.2). This was followed by uneconomical holding size (3.3), not aware of current dose of chemicals and fertilizers (3.3) and low cost of produce (4.5). The other constraints in the order of lesser importance were high cost of plant protection chemicals (5.5), lack of proper guidance (6.1), non availability of skilled labour (7.0) and non-availability of plant protection chemicals (7.1). The second least important constraint was lack of drainage (7.9) and least important was lack of irrigation facilities (8.9). The Kendall's co-efficient of concordance was 0.6261 and was significant. This showed that there was an agreement among the farmers on ranking of their constraints (Table 9).

The results of the pooled analysis of the constraints perceived by all the farmers in the four panchayats in Neyyattinkara taluk are presented in table 9. The most important constraint recognized in adoption of recommended practices in coconut was high cost of labour (average rank 1.32).This was followed by low cost of produce (3.60), uneconomical holding size (4.95) and lack of proper guidance (5.45). The other constraints in the order of lesser importance were high cost of plant protection chemicals (5.85), lack of irrigation facilities (5.92), not aware of current dose of chemicals and fertilizers (6.00) and non availability of plant protection chemicals (6.62). The second least important constraint was non availability of skilled labour (7.32) and the least important was lack of drainage (7.90).

4.2 Field evaluation of insecticides and botanicals for management of rhinoceros beetle in coconut palms.

The results on the extent of damage on palms were recorded from treated palms 15, 30 and 45 days after application of each treatment in May 2012, September 2012 and January 2013. The results are being presented.

Number of rhinoceros beetles after first application of treatments (May 2013).

The results of the analysis on number of rhinoceros beetle at different intervals after the first application of treatments (May 2012) expressed as mean number per five palms are presented in Table 10.

The least number of rhinoceros beetle adults (0.72 per five palms) was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.00 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.23 per five palms) treated palms, fifteen days after treatment (15 DAT) . The highest number of rhinoceros beetle adults (4.00 per five palms) was observed in the T9-untreated palms. At 15 DAT, there was no significant difference among the treatments and untreated with regard to the number of rhinoceros beetle adults (Table 10).

Thirty days after application of treatments (30 DAT), the lowest number of rhinoceros beetle adults were observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.73 per five palms) and T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.73 per five palms) treatments. The highest number of rhinoceros beetle adults (4.24 per five palms) was observed in untreated palms. At 30 DAT, the effect of treatments were statistically on par (Table 10).

Table 10. Number of rhinoceros beetles* at different intervals after first application of treatments (May 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatment means
T1-Crown cleaning + Cartap hydrochloride 4G (25 g) + sand (200 g) -leaf axil filling.	0.72 (1.31)	1.73 (1.65)	2.19 (1.79)	1.51 (1.58)
T2-Crown cleaning + Carbosulfan 6G (25 g) + sand (200 g) - leaf axil filling.	1.23 (1.49)	2.24 (1.80)	2.71 (1.92)	2.02 (1.74)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g)- leaf axil filling.	1.73 (1.65)	2.48 (1.87)	2.97 (1.99)	2.37 (1.84)
T4-Crown cleaning + Chlorpyriphos 1.5DP (50 g) + sand (200 g) -leaf axil filling.	2.48 (1.87)	3.49 (2.12)	4.00 (2.24)	3.30 (2.07)
T5-Crown cleaning + Fipronil 0.3G (100 g) + sand (200 g) - leaf axil filling.	2.24 (1.80)	3.00 (2.00)	3.49 (2.12)	2.89 (1.97)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g)- leaf axil filling.	1.00 (1.41)	1.73 (1.65)	2.70 (1.93)	1.77 (1.66)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g)- leaf axil filling.	1.96 (1.72)	2.48 (1.87)	3.74 (2.18)	2.69 (1.92)
T8-Farmers' practice (Only crown cleaning	3.00 (2.00)	3.74 (2.18)	4.49 (2.34)	3.72 (2.17)
T9-Untreated	4.00 (2.24)	4.24 (2.18)	5.00 (2.45)	4.40 (2.33)
CD (0.05)	NS			**(0.102)**

Transformed square root (√x+1) values are given in parentheses
*** In five palms**
****DAT – Days after treatment**
N.S – Non significant

Forty five days after application of treatments (45 DAT), the same trend was observed wherein the lowest population was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (2.19 per five palms) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (25 g) (2.70 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.71 per five palms) treated palms. The highest number of rhinoceros beetles was observed in T9-untreated palms (5.00 per five palms). The population of rhinoceros beetle did not significantly differ among the treatments at 45 DAT (Table 10).

The lowest number of rhinoceros beetle per five palms was observed (1.51 per five palms) in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) mixed with sand (200 g) which was statistically on par with the population (1.77 per five palms) in T6- crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) mixed with sand (200 g) treatment. The population was significantly higher in the T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (2.69 per five palms), crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) (2.89 per five palms), T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g)+ sand (200 g) (3.30 per five palms) and T8-farmers' practice (3.72 per five palms). The highest number of rhinoceros beetles per five palms was observed in T9-untreated palms (4.40) (Table 10).

Number of rhinoceros beetles in palms after second application of treatments (September 2012)

The results on analysis of number of rhinoceros beetles on in the palms at different intervals after the second application of treatments (September 2012) expressed as mean number per five palms are presented in table 11.

Fifteen days after treatment (15 DAT), the lowest number of rhinoceros beetle adults (0.22 per five palms) was recorded in T1-crown cleaning

Table 11. Number of rhinoceros beetles* at different intervals after second application of treatments (September 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatment means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) -leaf axil filling.	0.22 (1.10)	1.23 (1.49)	2.24 (1.80)	1.15 (1.47)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g)-leaf axil filling.	1.00 (1.41)	2.00 (1.73)	2.48 (1.87)	1.79 (1.67)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	1.23 (1.49)	2.24 (1.80)	3.00 (2.00)	2.11 (1.76)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) -leaf axil filling.	2.24 (1.80)	3.24 (2.06)	4.00 (2.24)	3.12 (2.03)
T5-Crown cleaning + Fipronil 0.3 G (100 g) + sand (200 g)-leaf axil filling.	2.00 (1.73)	3.00 (2.00)	3.49 (2.12)	2.80 (1.95)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g)- leaf axil filling.	1.00 (1.41)	1.23 (1.49)	2.24 (1.80)	1.46 (1.57)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g)- leaf axil filling.	2.00 (1.73)	2.48 (1.87)	3.24 (2.06)	2.56 (1.89)
T8-Farmers' practice (Only crown cleaning)	3.00 (2.00)	3.74 (2.18)	4.24 (2.29)	3.64 (2.16)
T9-Untreated	4.00 (2.24)	4.74 (2.40)	5.00 (2.45)	4.57 (2.36)
CD (0.05)	**(0.137)**			**(0.072)**

Transformed square root ($\sqrt{x+1}$) values are given in parentheses
*** In five palms**
****DAT – Days after treatment**

+ leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment which was significantly superior compared to all other treatments. T2-Crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.00 per five palms) and T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) which was on par with T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (1.23 per five palms) treatment. The highest number of rhinoceros beetle adults in five palms was observed in T9-untreated palms (4.00 per five palms) and in palms receiving T8-farmers' practice (crown cleaning only), the beetle count was 3.00 per five palms. (Table 11.)

Thirty days after treatment (30 DAT), the lowest number of rhinoceros beetle adults (1.23 per five palms) was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) and (1.23 per five palms) treatment. This was followed by T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.00 per five palms) which in turn was statistically on par with T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (2.24 per five palms) and T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (2.48 per five palms) treatment. The highest number of rhinoceros beetle adults was recorded in T9-untreated palms (4.74 per five palms) whereas in T8-farmer's practice (crown cleaning only) 3.74 adults per five palms were observed (Table 11.)

Forty five days after treatment (45 DAT), the lowest number of rhinoceros beetle adults was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (2.24 per five palms) and T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (2.24 per five palms) treated palms which was statistically on par with T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.48 per five palms), T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (3.00 per five palms). This in turn was statistically on

par with T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) (3.49 per five palms). The highest number of rhinoceros beetle adults was recorded in T9-untreated palms (5.00 per five palms) (Table 11).

The lowest number of rhinoceros beetle adults (1.15 per five palms) was recorded in palms by T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.46 per five palms) The next highest number of rhinoceros beetle adults was recorded in T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.79 per five palms) followed by T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (2.11 per five palms), T7-crown cleaning + leaf axil filling of chopped tobacco leaves (2.56 per five palms) treatments which was on par with treatment T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) (2.80 per five palms). The highest number of rhinoceros beetles was found in T9-untreated palms (4.57 per five palms) which was significantly higher compared to all the other treatments. The results of treatments in September 2012 indicated that T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G + sand (200 g) treatment was the best in reducing the number of rhinoceros beetle adults followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (Table 11).

Number of rhinoceros beetles in palms after third application of treatments (January 2013).

Fifteen days after treatment (15 DAT), the lowest number of rhinoceros beetle adults of (0.46 per five palms) was observed in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) , followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (0.72 per five palms), T2-crown cleaning

Table 12. Number of rhinoceros beetles* at different intervals after third application of treatments (January 2013).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) -leaf axil filling.	0.46 (1.21)	0.93 (1.39)	1.73 (1.65)	1.01 (1.42)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	1.23 (1.49)	1.73 (1.65)	2.74 (1.93)	1.87 (1.69)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g)- leaf axil filling.	1.47 (1.57)	2.19 (1.79)	2.97 (1.99)	2.18 (1.78)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	2.19 (1.79)	2.97 (1.99)	3.74 (2.18)	2.94 (1.99)
T5-Crown cleaning + Fipronil 0.3 G (100 g) + sand (200 g) leaf axil- filling.	1.73 (1.65)	2.74 (1.93)	3.49 (2.12)	2.61 (1.90)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g) -leaf axil filling.	0.72 (1.31)	1.73 (1.65)	2.24 (1.80)	1.52 (1.59)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	1.73 (1.65)	2.74 (1.93)	2.97 (1.99)	2.46 (1.86)
T8-Farmers' practice (Only crown cleaning)	2.74 (1.93)	3.74 (2.18)	4.00 (2.24)	3.47 (2.12)
T9-Untreated	4.00 (2.24)	4.24 (2.29)	5.00 (2.45)	4.40 (2.33)
CD (0.05)	**NS**			**(0.110)**

Transformed square root ($\sqrt{x+1}$) values are given in parentheses

*** In five palms**

****DAT – Days after treatment**

NS – Non significant

+ leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.23 per five palms), T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (1.47 per five palms), T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) (1.73 per five palms), T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (1.73 per five palms) treatments. The highest number of rhinoceros beetles was recorded in T9-untreated palms (4.00 per five palms). There was no significant difference among the treatments with regard to the population of rhinoceros beetles (Table 12).

Thirty days after treatment (30 DAT), the lowest number of rhinoceros beetle was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (0.93 per five palms) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.73 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.73 per five palms) treatment. The highest number of rhinoceros beetles was observed in T9-untreated (4.24 per five palms) closely followed by the population in T8-farmer's practice (crown cleaning) treatment. There was no significant difference among treatments and untreated palms on the number of rhinoceros beetles (Table 12).

The same trend of results was observed at 45 DAT, wherein the lowest number of rhinoceros beetles per five palms was found in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.73) treated palms followed by T6- crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (2.24). The highest number of rhinoceros beetle adults (5.00 per five palms) was observed in T9-untreated palms. The treatments including untreated palms were statistically on par with regard to the number of rhinoceros beetle adults (Table 12).

The lowest number of rhinoceros beetle (1.01 per five palms) was recorded in palms receiving T1-crown cleaning + leaf axil filling of cartap

hydrochloride 4 G (25 g) + sand (200 g) . The effect of this treatment was significantly superior to all other treatments. The mean number of rhinoceros beetle per five palms was significantly higher in the T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.52 per five palms) treated palms which was statistically on par with T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.87 per five palms) treatment. The population was higher in treatment palms receiving T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (2.18 per five palms), T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (2.46 per five palms), T5-fipronil 0.3 G (100 g) + sand (200 g) (2.61 per five palms) and T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) (2.94 per five palms). The maximum number of beetles (4.40 per five palms) was recorded in the untreated palms which was significantly higher compared to the treated palms (Table 12).

Fresh damage to crowns by rhinoceros beetle in coconut palms after first application of treatments (May 2012).

The lowest number of coconut crowns freshly damaged per five palms was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (0.93 per five palms) at 15 DAT. This was followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.00 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.47 per five palms) treated palms. The highest number of coconut crowns freshly damaged per five palms was revealed in T9-untreated palms (4.00). However, there was no significant difference among the treatments with regard to fresh damage on crowns (Table 13).

The lowest number of coconut crowns freshly damaged was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.47 per five palms) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.73 per five palms), T2-

crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.48 per five palms) and T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + (200 g) sand (2.48 per five palms) treated palms. The highest number of crowns freshly damaged was observed in the T9-untreated palms (4.24 per five palms). There was no significant difference among the treatments and T9-untreated palms on the number of coconut crowns freshly damaged 30 DAT.

The lowest number of coconut crowns freshly damaged was recorded in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 6 G (25 g) + sand (200 g) (2.19 per five palms) at forty five days after treatment (45 DAT). This is by T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) (2.19 per five palms) then crown cleaning + leaf axil filling of T6-crushed neem seed kernel (100 g) + sand (200 g) (2.71 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.71 per five palms) treatments. The maximum number of crowns freshly damaged per five palms was recorded in T9-untreated palms (5.00 per five palms). The treatments did not differ significantly in the number of crowns freshly damaged at 45 days after treatment.

The number of crowns freshly damaged per five palms was the lowest in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.51 per five palms) which was on par with crown cleaning + leaf axil filling of T6-crushed neem seed kernel (100 g) + sand (200 g) (1.77 per five palms). The damage was significantly higher in the other treatments. T2-Crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) treatments recorded 2.19 freshly damaged crowns per five palms. The number of crowns freshly damaged was significantly higher in the other treatments. The number of coconut crowns freshly damaged was the highest in T9-untreated palms (4.41 per five palms). The results indicated that after first application of treatments in May 2012, T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment was best in reducing

Table 13. Number of coconut crowns freshly damaged by rhinoceros beetle* at different intervals after first application of treatments (May 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	0.93 (1.39)	1.47 (1.57)	2.19 (1.79)	1.51 (1.58)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g)- leaf axil filling.	1.47 (1.57)	2.48 (1.87)	2.71 (1.93)	2.19 (1.79)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g)- leaf axil filling.	1.69 (1.64)	2.74 (1.93)	2.19 (1.79)	2.19 (1.79)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	2.48 (1.87)	3.24 (2.06)	4.00 (2.24)	3.22 (2.05)
T5-Crown cleaning + Fipronil 0.3 G (100 g) + sand (200 g)- leaf axil filling.	2.00 (1.72)	3.24 (2.06)	3.49 (2.12)	2.88 (1.97)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g) - leaf axil filling.	1.00 (1.41)	1.73 (1.65)	2.71 (1.93)	1.77 (1.66)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	2.19 (1.79)	2.48 (1.87)	3.49 (2.12)	2.70 (1.92)
T8-Farmers' practice (Only crown cleaning)	2.74 (1.93)	3.45 (2.11)	3.74 (2.18)	3.30 (2.07)
T9-Untreated	4.00 (2.24)	4.24 (2.29)	5.00 (2.45)	4.41 (2.33)
CD (0.05)	**NS**			**(0.123)**

Transformed square root ($\sqrt{x+1}$) values are given in parentheses
*** In five palms**
****DAT – Days after treatment**
NS – Non significant

the fresh damage to crowns by rhinoceros beetle adults followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + (200 g) sand (Table 13).

Fresh damage to crowns by rhinoceros beetle on coconut palms after second application of treatments (September 2012).

The results of the statistical analysis on number of coconut crowns freshly damaged by rhinoceros beetle adults at 15, 30 and 45 days after second application of treatments in September 2012 are presented in table 14.

Fifteen days after application of treatments (15 DAT), the lowest number of coconut crowns freshly damaged was 0.46 per five palms was recorded in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.00 per five palms), T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.23 per five palms) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) (1.23 per five palms) treatments. The highest number of coconut crowns freshly damaged (4.00 per five palms) was recorded in the T9-untreated palms. There was only numerical difference among the treatments and untreated palms on number of coconut crowns freshly damaged at fifteen days after treatment (Table 14).

Thirty days after application of treatments (30 DAT), the lowest number of coconut crowns freshly damaged was (1.23 per five palms) in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.47 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.00 per five palms) treatment. The highest number of coconut crowns freshly damaged was in the T9-untreated palms (4.74 per five palms) and in palms

receiving T8-farmers' practice (crown cleaning) the number of crowns freshly damaged was 3.74 per five palms. There was no significant difference among the treatments on number of coconut crowns freshly damaged at thirty days after treatment (Table 14).

The lowest number of coconut crowns freshly damaged was found in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (2.24 per five palms) treatment and T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (2.24 per five palms), followed by T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (2.48 per five palms) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) (3.00 per five palms) treatments at forty five days after application of treatments (45 DAT). The maximum number of coconut crowns freshly damaged per five palms was recorded in T9-untreated palms (5.00 per five palms). The treatments did not differ significantly in the number of crowns freshly damaged at 45 days after treatment (Table 14).

The number of coconut crowns freshly damaged per five palms was the lowest in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.25 per five palms) treatment which was on par with T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.54 per five palms). These treatments were significantly superior to the other treatments. The damage was higher in T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.88 per five palms) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) (2.11 per five palms) treatments. The number of crowns freshly damaged was significantly higher in the other treatments. The highest number of coconut crowns freshly damaged was in untreated palms (4.57 per five palms) which was significantly higher compared to the other treatments. The results indicated that after second application of treatments in September 2012, T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) +

Table 14. Number of coconut crowns freshly damaged by rhinoceros beetle* at different intervals after second application of treatments (September 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	0.46 (1.20)	1.23 (1.49)	2.24 (1.80)	1.25 (1.50)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g)- leaf axil filling.	1.23 (1.49)	2.00 (1.73)	2.48 (1.87)	1.88 (1.70)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	1.23 (1.49)	2.24 (1.80)	3.00 (2.00)	2.11 (1.76)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	2.00 (1.73)	3.00 (2.00)	4.00 (2.24)	2.95 (1.99)
T5-Crown cleaning + Fipronil 0.3 G (100 g)+ sand (200 g)- leaf axil filling.	2.00 (1.73)	3.00 (2.00)	3.49 (2.12)	2.80 (1.95)
T6-Crown cleaning + Crushed neem seed kerne (100 g)+ sand (200 g) - leaf axil filling.	1.00 (1.41)	1.47 (1.57)	2.24 (1.80)	1.54 (1.59)
T7-Crown cleaning + Chopped tobacco leaves (100 g)+ sand (200 g)- leaf axil filling.	2.45 (1.86)	2.48 (1.87)	3.24 (2.06)	2.72 (1.93)
T8-Farmers' practice (Only crown cleaning)	2.74 (1.93)	3.74 (2.18)	4.24 (2.28)	3.55 (2.13)
T9-Untreated	4.00 (2.24)	4.74 (2.40)	5.00 (2.45)	4.57 (2.36)
CD (0.05)	**NS**			**(0.095)**

Transformed square root ($\sqrt{x+1}$) values are given in parentheses
*** In five palms;**
****DAT – Days after treatment**
NS – Non significant

sand (200 g) treatment was the best in reducing the fresh damage to crown by rhinoceros beetle adults followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + (200 g) sand (Table 14).

Fresh damage to crown by rhinoceros beetle on coconut after application of treatments (January 2013)

The results on the statistical analysis on number of coconut crowns freshly damaged by rhinoceros beetle adults at 15, 30 and 45 days after third application of treatments in January 2013 are presented in table 15.

The lowest number of coconut crowns freshly damaged (0.46 per five palms) was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (0.72 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.23 per five palms) treatments. The number of fresh count damage was higher in other treatments. The highest number of coconut crowns damaged was (4.00 per five palms) recorded in the T9-untreated palms. There was no significant difference among the treatments and untreated palms on number of coconut crowns freshly damaged at 15 DAT.

Thirty days after application of treatments (30 DAT), T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms recorded the lowest number of coconut crowns freshly damaged (1.23 per five palms) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.73 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G + sand (200 g) (1.73 per five palms). The number of crowns freshly damaged ranged from 2.48 to 3.74 per five palms in the other treatments. The T9-untreated palms recorded the highest number of freshly damaged coconut crowns (4.00 per five palms). There

was no significant difference among treatments including untreated palms on number of coconut crowns freshly damaged 30 DAT (Table 15).

The lowest number of coconut crowns freshly damaged was observed in palms treated with T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (2.00 per five palms) followed by T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (2.24 per five palms) and T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (2.48 per five palms). The number of coconut crowns freshly damaged ranged from 2.97 to 4.24 per five palms in the palms receiving the other treatments. The maximum number of coconut crowns freshly damaged in T9-untreated palms (5.00 per five palms). There was no significant difference among treatments on number of coconut crowns freshly damaged 45 DAT (Table 15).

The number of coconut crowns freshly damaged per five palms was the lowest in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.18 per five palms) treatment. The effect of this treatment was significantly higher than all the other treatments. The second best treatment was T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.56 per five palms) which was statistically on par with T2-crown cleaning + leaf axil filling of carbosulfan 6 G 20g + sand (200 g) (1.87 per five palms) which in turn was on par with T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (1.96 per five palms) treatments. The number of crowns freshly damaged was significantly higher in the other treatments. The highest number of coconut crowns freshly damaged was in T9-untreated palms (4.32 per five palms) which was significantly higher compared to the other treatments. The results indicated that after third application of treatments in January 2013, T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment was best in reducing the fresh damaged to coconut crowns by rhinoceros beetle adults. T6-Crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) ranked second (Table 15).

Table 15. Number of coconut crowns freshly damaged by rhinoceros beetle* at different intervals after third application of treatments (January 2013).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	0.46 (1.21)	1.23 (1.49)	2.00 (1.73)	1.18 (1.47)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	1.23 (1.49)	1.73 (1.65)	2.74 (1.93)	1.87 (1.69)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	1.47 (1.57)	2.19 (1.79)	2.24 (1.80)	1.96 (1.72)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	2.19 (1.79)	3.00 (2.00)	4.00 (2.24)	3.03 (2.01)
T5-Crown cleaning + Fipronil 0.3 G (100 g) + sand (200 g) - leaf axil filling.	1.73 (1.65)	2.97 (1.99)	3.24 (2.06)	2.61 (1.90)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g) - leaf axil filling.	0.72 (1.31)	1.73 (1.65)	2.48 (1.87)	1.56 (1.61)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	1.73 (1.65)	2.48 (1.87)	2.97 (1.99)	2.37 (1.84)
T8-Farmers' practice (Only crown cleaning)	2.97 (1.99)	3.74 (2.18)	4.24 (2.29)	3.64 (2.15)
T9-Untreated	4.00 (2.24)	4.00 (2.24)	5.00 (2.45)	4.32 (2.31)
CD (0.05)	**NS**			**(0.100)**

Transformed square root (√x+1) values are given in parentheses
*** In five palms**
****DAT – Days after Treatment**
NS – Non significant

Fresh damage to spindles by rhinoceros beetle on coconut after first application of treatments (May 2012).

The lowest number of coconut spindles freshly damaged per five palms was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + (200 g) sand treatment (0.93 per five palms), followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + (200 g) sand treatment (1.47 per five palms), T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + (200 g) sand treatment (1.73 per five palms) and T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + (200 g) sand treatment (1.73 per five palms) 15 DAT. The damage was higher in the other treatments. The highest number of coconut spindles freshly damaged per five palms was observed on T9-untreated palms (4.00 per five palms). The treatments did not differ with regard to damage to fresh spindles at 15 DAT (Table 16).

The lowest number of coconut spindles freshly damaged was recorded in palms receiving T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.69 per five palms), followed by T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.96 per five palms) and T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) (2.24 per five palms). The highest number of spindles freshly damaged was observed in the T9-untreated palms (4.49 per five palms). The number of coconut crowns freshly damaged at 30 DAT did not differ among the treatments and untreated palms (Table 16).

The lowest number of coconut spindles freshly damaged was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.47 per five palms) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (2.24 per five palms), T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) (2.48 per five palms) and T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (2.71 per five palms)

Table 16. Number of coconut spindles freshly damaged by rhinoceros beetle* at different intervals after first application of treatments. (May 2012)

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	0.93 (1.39)	1.96 (1.72)	1.47 (1.57)	1.44 (1.56)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	2.48 (1.87)	2.97 (1.99)	3.21 (2.05)	2.88 (1.97)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	2.24 (1.80)	2.74 (1.93)	2.97 (1.99)	2.64 (1.91)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	1.73 (1.65)	2.24 (1.80)	2.48 (1.87)	2.14 (1.77)
T5-Crown cleaning + Fipronil 0.3 G (100 g) + sand (200 g) - leaf axil filling.	2.74 (1.93)	3.21 (2.05)	3.74 (2.18)	3.22 (2.05)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g)- leaf axil filling.	1.47 (1.57)	1.69 (1.64)	2.24 (1.80)	1.79 (1.67)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g)- leaf axil filling.	1.73 (1.65)	2.97 (1.99)	2.71 (1.93)	2.45 (1.86)
T8-Farmers' practice (Only crown cleaning)	3.49 (2.12)	3.74 (2.18)	4.00 (2.24)	3.74 (2.18)
T9-Untreated	4.00 (2.24)	4.49 (2.34)	5.00 (2.50)	4.49 (2.34)
CD (0.05)	**NS**			**(0.165)**

Transformed square root ($\sqrt{x+1}$) values are given in parentheses
*** In five palms**
****DAT – Days after treatment**
NS – Non significant

treatment. The highest number of spindles freshly damaged was in T9-untreated palms (5.00 per five palms). There was no significant difference among the treatments and untreated on the number of coconut spindles freshly damaged at 45 DAT (Table 16).

The number of spindles freshly damaged was the lowest in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.44 per five palms) which was statistically on par with T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.79 per five palms) treatment. This in turn was on par with T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) (2.14 per five palms) treatment. The number of spindles freshly damaged in T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) treatment was on par with T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (2.45 per five palms) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) treatments (2.64 per five palms) treatments. The number of spindles damaged was higher in the other treatments. The highest number of coconut spindles freshly damaged was in T9-untreated palms (4.49 per five palms) which were statistically on par with the damage (3.74 per five palms) in the farmer's practice (crown cleaning) (Table 16).

The results indicated that after first application of treatments in May 2012, T1-crown cleaning + leaf axil filling cartap hydrochloride 4 G (25 g) + sand (200 g) treatment was the best in reducing the fresh damage to spindles by rhinoceros beetle adults followed by T6-crown cleaning + leaf axil filling crushed neem seed kernel (100 g) + sand (200 g) treatment.

Fresh damage to spindles by rhinoceros beetle on coconut after second application of treatments (September 2012).

The lowest number of coconut spindles freshly damaged (1.00 per five palms) was recorded in T1-crown cleaning + leaf axil filling of

cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (1.47 per five palms), and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) treatment (2.00 per five palms). The highest number of coconut spindles freshly damaged (4.00 per five palms) was recorded in T9-untreated palms. There was no significant difference among the treatments and untreated on number of coconut crowns freshly damaged at 15 DAT (Table 17).

The lowest number of coconut spindles freshly damaged was in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment (1.73 per five palms) followed by crown cleaning + leaf axil filling of T6-crushed neem seed kernel (100 g) + sand (200 g) (1.73 per five palms) and T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) treatment (2.24 per five palms) at thirty days after treatment (30 DAT). The highest number of fresh spindles damaged was observed in T9-untreated (4.74 per five palms) and the spindle damage in T8-farmers' practice (crown cleaning) was 3.74 per five palms. There was no significant difference among treatments and untreated on the number of fresh spindles damaged at 30 DAT (Table 17).

The same trend was observed wherein the lowest number of fresh spindles damaged per five palm (2.00) was found in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment, followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (2.19 per five palms), and T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) treatment (2.24 per five palms) treatments. Fresh damage to spindles was the highest in untreated (5.00 per five palms) whereas in T8-farmers' practice (crown cleaning), the damage was 3.74 per five palms at 45 DAT (Table 17).

Table 17. Number of coconut spindles freshly damaged by rhinoceros beetle* at different intervals after second application of treatments (September 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G(25 g) + sand (200 g)- leaf axil filling.	1.00 (1.41)	1.73 (1.65)	2.00 (1.73)	1.56 (1.60)
T2-Crown cleaning + Carbosulfan 6 G(25 g) + sand (200 g) - leaf axil filling.	2.00 (1.73)	3.00 (2.00)	2.74 (1.93)	2.56 (1.89)
T3-Crown cleaning + Fenvalerate 0.4 DP 50+ sand (200 g) - leaf axil filling.	2.44 (1.85)	2.97 (1.99)	3.24 (2.06)	2.87 (1.97)
T4-Crown cleaning + Chlorpyriphos 1.5 DP(50 g) + sand (200 g) - leaf axil filling.	2.19 (1.79)	2.71 (1.93)	3.24 (2.06)	2.70 (1.92)
T5-Crown cleaning + Fipronil 0.3 G (100 g)+ sand (200 g)- leaf axil filling.	2.19 (1.79)	2.24 (1.80)	2.24 (1.80)	2.22 (1.80)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g) - leaf axil filling.	1.47 (1.57)	1.73 (1.65)	2.19 (1.79)	1.79 (1.67)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	2.74 (1.93)	2.48 (1.87)	2.71 (1.93)	2.64 (1.91)
T8-Farmers' practice (Only crown cleaning)	3.21 (2.05)	3.74 (2.18)	3.74 (2.18)	3.56 (2.14)
T9-Untreated	4.00 (2.24)	4.74 (2.40)	5.00 (2.45)	4.57 (2.36)
CD (0.05)		**NS**		**0.142**

Transformed square root (√x+1) values are given in parentheses
*** In five palms**
****DAT – Days after treatment**
NS – Non significant

The T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms recorded the lowest number of freshly damaged spindles (1.56 per five palms) which was statistically on par with T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (1.79 per five palms). This in turn was statistically on par with fipronil 0.3 G (100 g) + sand (200 g) treatment (2.22 per five palms). The damage was higher in T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) treatment, T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) treatment, T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g)+ sand (200 g) treatment, T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) treatment with 2.56, 2.64, 2.70 and 2.87 freshly damaged spindles per five palms respectively. The damage to fresh spindles was slightly higher in T8-farmers' practice (crown cleaning) (3.56 per five palms) and T9-untreated palms (4.57 per five palms). Pooled analysis revealed that T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment was the best in curtailing fresh damage to spindles after second application of treatments in September 2012 (Table 17).

Fresh damage to spindles by rhinoceros beetle on coconut after third application. (January 2013).

The lowest number of coconut spindles freshly damaged was T1-Crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms recorded the least fresh damage to spindles (1.23 per five palms), followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.47 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) treatment (1.96 per five palms). The fresh damage by rhinoceros beetle was higher in the other treatments. The highest number of freshly damaged spindles (4.00 per five palms) was recorded in the T9-untreated palms. The treatments and untreated did not differ on number of coconut spindles freshly damaged at 15 DAT (Table 18).

The lowest number of coconut spindles freshly damaged was 1.47 per five palms in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms which was on par with T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.47 per five palms) followed by T2-crown cleaning + leaf axil filling of carbosulfan 6 G + sand (200 g) (2.48 per five palms), T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (2.48 per five palms) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (2.48 per five palms) treatments. The highest number of coconut spindles freshly damaged was in T9-untreated palms (4.49 per five palms) whereas in palms receiving T8-farmers' practice (crown cleaning), the number of palms freshly damaged was 3.74 per five palms. There was no difference among treatments on the number of coconut spindles freshly damaged at 30 DAT (Table 18).

The lowest number of coconut spindles freshly damaged was in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment (1.96 per five palms) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (2.24 per five palms) at forty five days after treatment (45 DAT). The maximum number of coconut spindles freshly damaged per five palms was recorded in the untreated palms (5.00 per five palms). The treatments did not differ in the number of spindles freshly damaged at 45 DAT (Table 18).

The number of coconut spindles freshly damaged was lowest in palms treated with T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (1.54 per five palms) which was statistically on par with T6-crown cleaning + leaf axil filling of crushed neem seed kernel + sand (200 g) treatment (1.72 per five palms). The number of spindles freshly damaged was slightly higher in the other treatments, *viz.,* T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g)+ sand (200 g) , T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) , T5-crown cleaning + leaf axil filling

Table 18. Number of coconut spindles freshly damaged by rhinoceros beetle* at different intervals after third application of treatments (January 2013).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	1.23 (1.49)	1.47 (1.57)	1.96 (1.72)	1.54 (1.60)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	1.96 (1.72)	2.48 (1.87)	2.74 (1.93)	2.38 (1.84)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	2.00 (1.73)	2.48 (1.87)	3.00 (2.00)	2.48 (1.87)
T4-Crown cleaning + Chlorpyriphos 1.5 DP(50 g) + sand (200 g)- leaf axil filling.	2.24 (1.80)	2.71 (1.93)	3.74 (2.18)	2.87 (1.97)
T5-Crown cleaning + Fipronil 0.3 G (100 g)+ sand (200 g) - leaf axil filling.	2.00 (1.73)	2.48 (1.87)	3.00 (2.00)	2.48 (1.87)
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g)- leaf axil filling.	1.47 (1.57)	1.47 (1.57)	2.24 (1.80)	1.72 (1.65)
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	2.24 (1.80)	2.48 (1.87)	3.00 (2.00)	2.56 (1.89)
T8-Farmers' practice (Only crown cleaning)	3.49 (2.12)	3.74 (2.18)	4.00 (2.24)	3.74 (2.18)
T9-Untreated	4.00 (2.24)	4.49 (2.34)	5.00 (2.45)	4.50 (2.34)
CD (0.05)	**NS**			**(0122)**

Transformed square root ($\sqrt{x+1}$) values are given in parentheses
*** In five palms**
****DAT – Days after treatment**
NS – Non significant

of fipronil 0.3 G (100 g) + sand (200 g) , T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) and T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) with spindle damage to the tune of 2.38, 2.48, 2.48 , 2.56 and 2.87 per five palms. The highest number of spindles freshly damaged was in T9-untreated (4.50 per five palms) which was significantly higher compared to the other treatments including farmers' practice (crown cleaning only) (3.74 per five palms). The results indicated that after third application of treatments in January 2013, the best treatment for containing fresh damage by rhinoceros beetle to spindles was T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (Table 18).

Fresh damage on spathes by rhinoceros beetle after first application of treatments in May 2012.

Percentage of spathes freshly damaged fifteen days after application of treatments (15 DAT)

Fifteen days after application of treatments (15 DAT), none of spathes exhibited fresh damage by rhinoceros beetle in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms. The percentage of fresh spathes damaged per five palms in T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) , T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g), T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) , T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) treatments were 5.00, 10.00, 10.00, 10.00 and 10.00, respectively. The highest percentage of spathes freshly damaged by rhinoceros beetle was observed in T9-untreated palms (35.00 per five palms) and in the T8-farmers' practice

(crown cleaning only), the damage was 30.00 per cent per five palms at 15 DAT (Table 19).

Percentage of spathes freshly damaged thirty days after application of treatments (30 DAT).

T1-Crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms recorded the lowest percentage of freshly damaged spathes (5.00 per five palms). This was followed by T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) and T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) treatments where 10.00 per cent of the spathes were freshly damaged. The extent of damage was to the tune of 20.00 per cent in T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) and 30.00 per cent in T8-farmers' practice (crown cleaning). The highest percentage of freshly damaged spathes by rhinoceros beetle was obtained in T9-untreated palms (40.00 per five palms) at 30 DAT (Table 19).

Percentage of spathes freshly damaged forty five days after application of treatments (45 DAT)

The lowest percentage of spathes freshly damaged by rhinoceros beetle (15.00 per five palms) was obtained in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (20.00 per five palms). The fresh damage to spathes ranged from 25.00 to 30.00 per cent in all the other treatments. The highest percentage of spathes freshly damaged was recorded in untreated palms (40.00 per five palms) at 45 DAT (Table 19).

Table 19. Percentage of coconut spathes freshly damaged by rhinoceros beetle* at different intervals after first application of treatments (May 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatments means
T1-Crown cleaning + Cartaphydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	0.00	5.00	15.00	6.66
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	10.00	10.00	25.00	15.00
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	10.00	15.00	25.00	16.66
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	15.00	20.00	25.00	20.00
T5-Crown cleaning + Fipronil 0.3 G (100 g)+ sand (200 g) - leaf axil filling.	10.00	10.00	30.00	16.66
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g) - leaf axil filling.	10.00	15.00	20.00	15.00
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	5.00	15.00	25.00	15.00
T8-Farmers' practice (Only crown cleaning)	30.00	30.00	35.00	31.66
T9-Untreated	35.00	40.00	40.00	38.33

*** In five palms**

****DAT – Days after treatment**

Mean percentage of spathes infested at different intervals after first application (May 2012).

The lowest percentage of spathes freshly damaged by rhinoceros beetle adults (6.66 per five palms) was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (15.00 per five palms), T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (15.00 per five palms) and T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) (15.00 per five palms) treatments. The percentage of spathes damaged in T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) and farmers' practice (crown cleaning only) were 20.00 and 31.66 per five palms respectively. The highest percentage of spathes damaged by rhinoceros beetle adults was in untreated palms (38.33 per five palms) (Table 19).

After the first round of treatments in May 2012, T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) was the most effective treatment in reducing the fresh damage by rhinoceros beetle to coconut spathes

Fresh damage on spathes by rhinoceros beetle after second application of treatments in September 2012.

The results of the analysis on percentage of spathes freshly damaged by rhinoceros beetle at different intervals after second application of treatments (September 2012) expressed as mean percentage per five palms are presented in table 20.

Percentage of spathes freshly damaged fifteen days after application of treatments (15 DAT)

Fifteen days after treatment (15 DAT), the percentage of spathes freshly damaged was 5.00 per five palms with T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) , T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) treated palms. All the other treatments except T8-farmers' practice recorded a damage of 10.00 per cent. The per cent damage to spathes was 30.00 in farmers' practice (crown cleaning only) and the maximum was observed in the T9-untreated palms (45.00 per five palms) (Table 20).

Percentage of spathes freshly damaged thirty days after application treatments (30 DAT)

Thirty days after treatment (30 DAT), the lowest percentage of spathes freshly damaged (10.00 per five palms) was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) , T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) treated palms. The damage ranged from 20.00 to 35.00 per cent in all the other treatments and the highest was recorded in untreated (40.00 per five palms) (Table 20).

Percentage of spathes freshly damaged forty five days after application of treatments (45 DAT)

Forty five days after treatments (45 DAT), 10.00 per cent of the spathes were freshly damaged in T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) , T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) , T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) , T4-crown cleaning + leaf axil filling

Table 20. Percentage of coconut spathes freshly damaged by rhinoceros beetle* at different intervals after second application of treatments (September 2012).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatment means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	5.00	10.00	15.00	10.00
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	5.00	20.00	10.00	11.66
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	5.00	10.00	20.00	11.66
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	10.00	20.00	10.00	13.33
T5-Crown cleaning + Fipronil 0.3 G(100 g) + sand (200 g)- leaf axil filling.	10.00	30.00	10.00	16.66
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g)- leaf axil filling.	10.00	10.00	10.00	10.00
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	10.00	25.00	10.00	15.00
T8-Farmers' practice (Only crown cleaning)	30.00	35.00	35.00	33.33
T9-Untreated	45	40	50	45.00

*** In five palms**

****DAT – Days after treatment**

of chlorpyriphos 1.5 DP (50 g) + sand (200 g) and T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) treated palms. The percentage of spathes freshly damaged in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g), T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) and T8-farmers' practice (crown cleaning only) were 15.00, 20.00 and 35.00 respectively. The highest percentage of spathes freshly damaged by rhinoceros beetle was recorded on the untreated palms (50.00 per five palms) at 45 DAT (Table 20).

Mean percentage of spathes infested at different intervals after second application (September 2012).

The lowest percentage of spathes freshly damaged (10.00 per five palms) by rhinoceros beetle was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) and T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treated palms. The next highest percentage of spathes freshly damaged by rhinoceros beetle adults was recorded in T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (11.66 per five palms) treated palms. The damage ranged from 15.00 to 33.33 per cent in the palms receiving the other treatments (Table 20).

Among the treatments applied the second time in September 2013, the best one was T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) in containing fresh damage to coconut spathes.

Fresh damage on spathes by rhinoceros beetle after third application of treatments in January 2013.

The results of the analysis on percentage of spathes freshly damaged by rhinoceros beetle at different intervals after third application of treatments (January 2013) expressed as mean percentage per five palms are presented in table 21.

Percentage of spathes freshly damaged fifteen days after application of treatments (15 DAT).

Fifteen days after application of treatments (DAT), the lowest percentage of spathes freshly damaged (5.00 per five palms) was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g), T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) , T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) treated palms. The damage was higher (10.00 to 20.00 per cent) in the other treatments including T8-farmers' practice (crown cleaning only). The highest percentage of spathes freshly damaged by rhinoceros beetle adults was observed in untreated (40.00 per five plams) (Table 21).

Percentage of spathes freshly damaged thirty days after treatment (30 DAT)

Thirty days after application of treatments (30 DAT), T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) , T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) treatments recorded the lowest damage of 5.00 per cent freshly damaged spathes per five palms. The next highest percentage of spathes freshly damaged by rhinoceros beetle adults (10.00 per five palms) was observed in T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) and T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand

Table 21. Percentage of coconut spathes freshly damaged by rhinoceros beetle* at different intervals after third application of treatments (January 2013).

Treatments	15 DAT**	30 DAT**	45 DAT**	Treatment means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	5.00	5.00	5.00	5.00
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g) - leaf axil filling.	5.00	5.00	10.00	6.66
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	5.00	15.00	5.00	8.33
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	10.00	10.00	15.00	11.66
T5-Crown cleaning + Fipronil 0.3 G (100 g) + sand (200 g) - leaf axil filling.	10.00	15.00	10.00	11.66
T6-Crown cleaning + Crushed neem seed kernel (100 g) + sand (200 g) - leaf axil filling.	10.00	5.00	10.00	8.33
T7-Crown cleaning + Chopped tobacco leaves (100 g) + sand (200 g) - leaf axil filling.	5.00	10.00	25.00	13.33
T8-Farmers' practice (Only crown cleaning)	20.00	35.00	30.00	28.33
T9-Untreated	40.00	40.00	35.00	38.33

*** In five palms**

****DAT – Days after treatment**

(200 g) treatments. The percentage of fresh damage to spathes was 35.00 in T8-farmers' practice (crown cleaning only) and maximum damage of 40.00 per cent was recorded in the T9- untreated palms (Table 21).

Percentage of spathes freshly damaged forty five days after application of treatments (45 DAT).

Forty five days after application of treatments (45 DAT), the lowest percentage of spathes freshly damaged by rhinoceros beetle adults (5.00 per five palms) was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) treatments. This was followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) , T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) and T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) treated palms where 10.00 per cent damage was recorded. The damage ranged from 15.00 to 30.00 per cent in the other treatments. The highest percentage of spathes freshly damaged (35.00 per five palms) by rhinoceros beetle adult was recorded in the T9-untreated palms.

Mean percentage of spathes infested at different intervals after third application (January 2013).

The percentage of coconut spathes freshly damaged per five palms was the lowest (5.00 per five palms) in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) treated palms which was followed by T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (6.66 per five palms) treatments. The percentage of spathes freshly damaged by rhinoceros beetle adults was higher in palms receiving T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) treatment (8.33 per five palms). The fresh damage to spathes was higher (11.66 to 28.33 per

cent) in the other treatments. The highest percentage of spathes freshly damaged by rhinoceros beetle adults was recorded in untreated (38.33 per five palms) (Table 21).

The most effective treatment after third application in January 2013 in reducing the fresh damage to coconut spathes by rhinoceros beetle was T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g).

Number of freshly emerged bunches exhibiting infestation by rhinoceros beetle forty five days after treatments.

The results on the analysis on the number of emerged bunches exhibiting infestation by rhinoceros beetle forty five days after application of treatments in May 2012, September 2012 and January 2013 are presented in table 22.

Forty five days after first application of treatments in May 2012 (45 DAT).

Forty five days after first application of treatments (45 DAT), the lowest number of freshly emerged bunches exhibiting infestation by rhinoceros beetle adults (0.46 per five palms) was observed in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.00 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.23 per five palms) treatments. The number of emerged bunches damaged by the beetle was higher in the other treatments. The highest number of emerged bunches exhibiting infestation by rhinoceros beetle adults (4.00 per five palms) was observed in untreated palms. Forty five days after first application of treatments, there was no significant difference among the treatments and untreated with regard to number of emerged bunches exhibiting infestation by rhinoceros beetle (Table 22).

Forty five days after second application of treatments in September 2012 (45 DAT).

Forty five days after second application of treatments (45 DAT), the same trend was observed wherein the lowest number of freshly emerged bunches exhibiting infestation was recorded in palms receiving T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (0.72 per five palms), followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (1.00 per five palms) and T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g) + sand (200 g) (1.23 per five palms) treatments. The highest number of emerged bunches exhibiting infestation by rhinoceros beetle adults (3.74 per five palms) was observed in T9-untreated palms. The number of emerged bunches exhibiting infestation by rhinoceros beetle did not differ among the treatments at 45 DAT after the second round of treatments in September 2012 (Table 22).

Forty five days after third application of treatments in January 2013 (45 DAT)

Forty five days after third application of treatments (45 DAT), T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treated palms exhibited the least number of emerged bunches infested by rhinoceros beetle (0.46 per five palms) followed by T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) (0.72 per five palms) and T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) (1.00 per five palms) treated palms. The highest number of fresh bunches exhibiting infestation by rhinoceros beetle adults (3.49 per five palms) were observed in T9-untreated palms. At 45 DAT, there was no difference among the treatments and untreated with regard to the number of emerged bunched exhibiting infestation by rhinoceros beetle (Table 22).

Table. 22. Number of emerged bunches exhibiting fresh infestation by rhinoceros beetle* forty five days after each application of treatments.

Treatments	1st Application** (May 2012)	2nd Application** (September 2012)	3rd Application** (January 2013)	Treatments means
T1-Crown cleaning + Cartap hydrochloride 4 G (25 g) + sand (200 g)- leaf axil filling.	0.46 (1.21)	0.72 (1.31)	0.46 (1.21)	0.54 (1.24)
T2-Crown cleaning + Carbosulfan 6 G (25 g) + sand (200 g)- leaf axil filling.	1.23 (1.49)	1.23 (1.49)	1.00 (1.41)	1.15 (1.47)
T3-Crown cleaning + Fenvalerate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	1.47 (1.57)	1.23 (1.49)	1.00 (1.41)	1.23 (1.49)
T4-Crown cleaning + Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	2.00 (1.73)	2.00 (1.73)	2.00 (1.73)	2.00 (1.73)
T5-Crown cleaning + Fipronil 0.3 G(100 g)+ sand (200 g) - leaf axil filling.	1.73 (1.65)	1.73 (1.65)	1.73 (1.65)	1.73 (1.65)
T6-Crown cleaning + Crushed neem seed kernel (100 g)+ sand (200 g)- leaf axil filling.	1.00 (1.41)	1.00 (1.41)	0.72 (1.31)	0.90 (1.38)
T7-Crown cleaning + Chopped tobacco leaves (100 g)+ sand (200 g) - leaf axil filling.	1.74 (1.65)	1.74 (1.65)	1.47 (1.57)	1.64 (1.63)
T8-Farmers' practice (Only crown cleaning)	2.74 (1.93)	2.74 (1.93)	2.48 (1.87)	2.65 (1.91)
T9-Untreated	4.00 (2.24)	3.74 (2.18)	3.49 (2.12)	3.74 (2.18)
CD(0.05)	**NS**			**(0.109)**

Transformed square root (√x+1) values are given in parentheses
*** In five palms**
**** Application of treatments**
NS – Non significant

Pooled analysis of the three applications of treatments.

The lowest number of freshly emerged bunches exhibiting fresh infestation by rhinoceros beetle was observed in palms treated with T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) (0.54 per five palms). This was significantly lower compared to T6-crown cleaning + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (0.90 per five palms). Treatment involving neem seed kernel was statistically on par with T2-crown cleaning + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) treatment (1.15 per five palms). This was followed by T3-crown cleaning + leaf axil filling of fenvalerate 0.4 DP (50 g)+ sand (200 g) treatment (1.23 per five palms). The number of emerged bunches exhibiting infestation was slightly higher in T7-crown cleaning + leaf axil filling of chopped tobacco leaves (100 g) + sand (200 g) treatment (1.64 per five palms), T5-crown cleaning + leaf axil filling of fipronil 0.3 G (100 g) + sand (200 g) treatment (1.73 per five palms) and T4-crown cleaning + leaf axil filling of chlorpyriphos 1.5 DP (50 g) + sand (200 g) treatment (2.00 per five palms) treated palms. The number of bunches showing fresh infestation at 45 DAT was higher in T8-farmers' practice (crown cleaning only) (2.65 per five palms) compared to chlorpyriphos treatment. The highest number of emerged bunches exhibiting infestation (3.74 per five palms) was observed in untreated palms which was significantly higher compared to the infestation in all the other treatments (Table 22).

The results showed that T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment was the best in limiting the fresh infestation by rhinoceros beetle on emerged bunches 45 DAT.

DISCUSSION

5. DISCUSSION

The coconut palm is the most common tree crop in the various cropping systems of Kerala. The crop farming systems in the State range from monoculture to multispecies cropping and includes the homestead farming system also. The coconut based farming system occupies about 90 per cent of the homestead farms and coconut is essentially a crop of the small land owners in Kerala. The State has about nineteen crore palms of different ages. Any problem or menace to the coconut palm will have a direct or indirect adverse effect not only on the economy of the State but also on the livelihood of the people connected to coconut. In the present times, the low productivity of coconut can be attributed to several causes. One among them is due to the ravages of pests. The pests attacking coconut palms include insects, mites, nematodes, rodents etc.

Among the pests infesting coconut, the rhinoceros beetle *Oryctes rhinoceros* L. is a major one. The damage by the beetle reduces the vigour and yield of the palm and predisposes it to other pests and diseases. The ubiquitous presence of the coconut palm ensures the availability of food and shelter for the rhinoceros beetle. Alexander and Peter (2005) reported that close spacing of the palms in Kerala resulted in the presence of 215 numbers per ha compared to the recommended number of 175 per ha. Poor sanitation in the breeding places encourages the population build up of the pest. Moreover, the single stem stand of the coconut palm renders the control of the rhinoceros beetle, a difficult and expensive proposition.

Information on farmers, their coconut gardens, crop husbandry practices including plant protection followed, constraints in adoption of recommended practices in coconut, status of rhinoceros beetle as a pest and its extent of infestation are limited. This is required for development of new strategies to tackle the pest. There is a lack of suitable chemical pesticide and botanical recommendations against the beetle. In this context, a study was undertaken to understand the profile of existing coconut gardens, crop husbandry practices

followed, the status of rhinoceros beetle as a pest, its infestation in coconut and to evolve chemical management measures using new generation insecticides and botanicals to control the beetle.

5.1 Survey on the extent of rhinoceros beetle infestation.

The coconut rhinoceros beetle has gained infamy as a key pest of coconut and has been studied by several scientists in the coconut growing countries of the world. The beetle has been reported to affect the yield and productivity of coconut palms in Kerala.

Precise information on the incidence of the beetle and its damage to coconut in the present scenario was required to develop strategies to contain it. In this context, a survey was conducted in Neyyattinkara taluk, Thiruvananthapuram district in 2012.The survey encompassed 40 farmers' fields in four panchayats *viz.,* Chenkal and Perumpazhuthoor (midland) and Thirupuram and Kottukal (coastal). The details of the farmers and their coconut gardens, crop husbandry practices and constraints in adoption of recommended practices in coconut were recorded and analysed. The population of the beetle was monitored and extent of infestation was determined. The findings of the survey are discussed.

The surveys revealed that higher percentage of farmers (55.00) were above 50 years of age. The rest of the farmers were distributed in three lesser age groups. About 95.00 per cent had a minimum education of SSLC and some of them had industrial training. This information revealed the education profile of the coconut farmers. Steps have to be taken to empower the younger farmers (< 50 years) to take up proper crop husbandry in coconut.

Most of the holdings surveyed (50.00 per cent) had an area of 50 to 100 cents and 45.00 per cent of the farmers had 50 to 100 cents under coconut. These observations concurred with the findings of Jnanadevan (2013). More than 70.00 per cent of the land was garden land. 87.50 per cent of the palms belonged to the West Coast Tall (WCT) variety and only 5.00 per cent of the palms were hybrids. This may be due to non availability of hybrid seedlings. This finding was

supported by Bastine *et al.,* (1991) and Jnanadevan and Prakash (1994). They also reported that high yielding hybrid varieties were not available in sufficient numbers for planting in Kerala. Jnanadevan (2013) also reported on the non availability of sufficient quantity of improved hybrids to meet the demand of the farmers. Only limited number of the high yielding hybrids like Lakshaganga, Anandaganga, Keraganga, Kerasree etc are available. This is an important issue that has to be addressed. Another observation was that 55.00 per cent of the palms were above 40 years and the yield was less than 40 nuts per palm per year in 82.50 per cent of the palms. The average yield of nuts per palm per year in Kerala has been pegged at 38 in 2011 (Farm Information Bureau, 2013). Perusal of the data revealed that the palms were planted at a closer spacing than the recommended 7.5 x 7.5 m in 80.00 per cent of the coconut gardens. Similar observations were made by Alexander and Peter (2005). Higher level of infestation of rhinoceros beetle on the palms could be attributed to the close spacing. Only 12.50 per cent of the gardens were irrigated and the rest depended on the rains. As per the reports of Farm Information Bureau (2013) the gross area under irrigation in coconut is only 20.00 per cent in Kerala. Menon and Pandalai (1958) stated that inspite of high annual rainfall in the west coast of India, drought like conditions occur for four to five months. This affected the growth and productivity of the coconut palms. More or less similar conditions are also prevailing at present. Irrigation during summer months in the different soil types of Kerala has been recommended by KAU (2011). This would bring about considerable improvement in the yield of the palms. With regard to the use of manures, cowdung was the preferred manure and used by about 60.00 per cent of farmers. The survey revealed that only 20.00 per cent of the farmers applied the dose of fertilizers recommended by KAU (2011). The above findings indicated that the crop husbandry practices adopted by farmers has resulted in the low yield and productivity of coconut in the survey area. In general coconut is not cultivated as a commercial crop in Kerala.

With regard to the plant protection measures adopted by the farmers to contain the beetle on coconut, only 30.00 per cent of the farmers conducted cultural measures like sanitation and crown cleaning. These operations were conducted along with the harvest of the coconut palms. The adoption of mechanical, biological, organic (botanicals) and chemical methods was very low. None of the farmers practised Integrated Pest Management (IPM) against the beetle. These observations concurred with the findings of Mahadik *et al.,* (2009). Jnanadevan (2013) also reported that plant protection has not been adopted on a wide scale on coconut in Kerala.

The survey revealed that the percentage of palms showing infestation ranged from 72.00 to 83.00 in the different panchayats (table 1.)The percentage of leaves damaged ranged from 35.86 to 56.41 in the coconut gardens surveyed. This showed the high level of infestation by the beetle. This affected the photosynthetic efficiency of the leaves which adversely affected the yield of the palms. This finding is in agreement with the findings of Nair and Visalakshi (1999). Most of the palms surveyed were above 40 years and they had more compact crowns and therefore had more leaves affected by rhinoceros beetle attack compared to younger palms. Similar observations were made by Cumber (1957) in Western Samoa and Hinckley (1966) in the Pacific Islands.

The percentage of palms showing fresh infestation to the crown by the beetle ranged from 23.64 to 27.27 in the different panchayats (table 2.) This obviously indicated that the beetle population was high in the coconut gardens surveyed. The structure of the coconut crown in relation to rhinoceros beetle attack has been described comprehensively by Young (1975).

The percentage of the central spindles infested by the beetle in the surveyed palms was high and ranged from 27.00 to 42.00 per cent (table 2.) The spindle or the central cluster consisted of very young fronds which were not yet unfurled to expose the leaflets. Mackie (1917) described the mode of attack and

the damage to the spear cluster in the coconut crown. The damage to the central spindle affected the production of good healthy fronds in the infested palms.

The fresh damage to the spathes was studied and the results revealed that the percentage of spathes freshly damaged ranged from 13.07 to 15.61 in the four panchayats (table 2). The study revealed that seven to nine per cent of the older spathes had dried due to boring and feeding of the rhinoceros beetle. Ramachandran (1961) discussed the nature of attack by the rhinoceros beetle on the coconut spathe and consequent drying up of the spathe. Boring into the spathe and damaging the spadix was more dangerous compared to the leaf damage as the inflorescence was directly affected. Similar observations were made by Nair and Visalakshi (1999).

The selected four hundred palms were observed for damage by coreid bug, eriophyid mite, mealy bugs and red palm weevil in the four panchayats.

The survey revealed that altogether, nuts of about 34.00 per cent of the palms were attacked by the coreid bug. The percentage of palms infested (56.00) was the highest in Perumpazhuthoor, a midland panchayat and lesser in the coastal panchayats. This finding differed from the observations of Paul (2006) who reported that the damage by coreid bug was more in the coastal region compared to mid land.

The percentage of palms showing infestation of mite on buttons and nuts was 35.00 per cent out of the total number of four hundred palms observed. However, the damage was in varying intensities and in general was low. The mite infestation was very serious ten to fifteen years before (Naseema *et al.,* 2004). The intensity of infestation has declined over the years probably due to the natural control exerted by predatory mites and pathogenic micro organisms on the mite.

Mealy bug infestation was observed in ten per cent of the total four hundred palms surveyed. The infestation was higher in Perumpazhuthoor compared to the other panchayats. The damage to the spindle leaves and bunches

was severe in the infested palms. The findings were in agreement to the observations made by Bindu (2003).

The percentage of palms infested by red palm weevil was only 0.50. The severely infested and toppled palms were not observed in the survey areas of the four panchayats. This was probably due to the removal of the palms heavily infested by the red palm weevil, other pests and diseases by the farmers under schemes of the Coconut Development Board. Jnanadevan (2013) reported that red palm weevil was a major problem in gardens where new palms are grown for reviving coconut gardens.

The percentage of palms exhibiting bud rot symptoms was 11.50 out of the total palms observed. The infestation was not severe at the time of survey in the month of May 2012. The infestation could become more severe with the advent of the monsoon season. However, the incidence of leaf rot disease (LRD) was higher compared to bud rot. As a whole, about 31.00 per cent of the palms were exhibiting leaf rot symptoms in varying degrees. The percentage of palms infected by leaf rot disease was 48.00 in Thirupuram, a coastal panchayat. Severe leaf rot disease has been reported in Kerala by CPCRI (2000) and Peethambaran *et al.*, (2008).

It was obvious that the incidence of the pests and diseases adversely affected the yield and productivity of the palms in the survey area. About 83.00 per cent of the palms yielded less than forty nuts per palm per year. The important constraints standing in the way of adopting recommended management measures was the high cost of labour and low cost of produce. Jnanadevan (2013) opined that the lack of skilled climbers to apply chemicals and the general reluctance of the farmers to use chemicals were the reasons for low level of adoption of plant protection measures.

The survey revealed that crops like banana, arecanut, pineapple, ornamental palms etc were not attacked by the rhinoceros beetle. This was in contrast to the reports of other hosts of the rhinoceros beetle like various species

of palms, sugarcane, pineapple, banana, arecanut etc. by Menon and Pandalai (1958), Wood (1968), Nair (1975), Norman and Basri (1997), Regupathy *et al.*, (1997) and CPC (2011). The availability of the principal food source *viz.*, closely planted coconut palms of different ages in the panchayats surveyed could be the reason for the rhinoceros beetle not infesting other hosts.

The beetle damage on leaves, spathes and central spindles were recorded in May 2012. The weather parameters *viz.*, maximum and minimum temperature, relative humidity morning and evening and number of rainy days of the preceeding 20 days were used for correlation studies. Correlations were worked out in two panchayats of Neyyattinkara taluk *viz.*, Perumpazhuthoor and Thirupuram. The percentage of leaves and spathes infested was negatively correlated with the maximum temperature in the two panchayats. The percentage of central spindles infested was negatively correlated to maximum temperature in Perumpazhuthoor panchayat and *vice versa* in Thirupuram panchayat.

The percentage of leaves, spathes and spindles infested was positively correlated to the minimum temperature in the two panchayats. The relative humidity in the morning as well as afternoon was negatively correlated to percentage of leaves infested in Perumpazhuthoor panchayat. In Thirupuram panchayat, relative humidity in the morning and afternoon were negatively and positively correlated respectively with leaves infested by beetle. In general, relative humidity was positively correlated to the percentage of spathes infested in Perumpazhuthoor panchayat and *vice versa* in Thirupuram panchayat. A similar trend was observed with regard to the correlation between relative humidity and percentage of central spindles infested in the two panchayats. The number of rainy days was positively correlated to the percentage of damage to leaves, spathes and central spindles infested by the beetle in the two panchayats. Rainfall has been reported to increase the population and damage of the rhinoceros beetle by Bedford (1975), Zelazny and Alfiler (1987) and Norman and Basri (2004).

In general, there was no significant correlation between the weather parameters and the percentage of leaves, spathes and central spindles infested by the rhinoceros beetle. The average maximum and minimum temperature of the preceeding 20 days before survey on beetle damage was 31.15 ^{o} C and 23.10 ^{o} C respectively. The average relative humidity morning and evening were 92.25 and 64.35 per cent respectively. There were rainy days during the 20 days prior to survey of beetle damage to palms. The dry weather along with high relative humidity and rains were very conducive for rhinoceros beetle activity and consequent damage to the leaves, spathes and central spindles in the palms of Thirupuram and Perumpazhuthoor panchayats. Similar observations have been recorded by Menon and Pandalai (1958) and Rao (2003). Rao (2003) reported that during the summer, the climatic factors were very favourable for the rhinoceros beetle and unfavourable for its natural enemies in Kerala.

Aggregation pheromone trap (four) were installed in four farmers' coconut gardens in the four panchayats and the catches of the beetle were recorded at fortnight intervals from May 2012 to July 2012. An average of the total number of beetles trapped per fortnight in the four panchayats worked out to 12.49. Out of this, the numbers of males were 6.62 and females, 5.87 which was 53.00 and 47.00 percent respectively of the total. In pheromone traps studies, Gressit (1953) also collected more male beetles than female beetles. However Bedford and Maddison (1972) caught more females compared to males in a rhinoceros beetle eradication programme in Fiji.

The results of the experiment indicated that aggregation pheromone traps could be used successfully for monitoring as well as mechanical control of the rhinoceros beetle. The use of aggregation pheromone traps in lowering the extent of infestation by the rhinoceros beetle has been demonstrated in oil palm by Zelazny and Alfiler (1987) and Ponnamma *et al.,* (2002). Josephrajkumar *et al.,* (2012), TNAU Expert System (2013) and Chandrika and Josephrajkumar (2013) recommended the installation of pheromone traps to catch the beetle.

The results of correlation studies between number of rhinoceros beetles collected in pheromone traps at fortnightly intervals and weather parameters are discussed.

In all the four panchayats, the average number of rhinoceros beetles collected in pheromone traps per fortnight was positively correlated with both maximum and minimum temperature but it was not statistically significant. The average number of beetles trapped was negatively correlated with relative humidity morning and afternoon. In Chenkal and in Thirupuram panchayats, the number of beetles trapped was significantly correlated with relative humidity (morning). The catch of rhinoceros beetles per fortnight was positively correlated with number of rainy days but the relationship was not significant statistically. Menon and Pandalai (1958) reported that rainfall during dry weather resulted in emergence of a large number of beetles. The present correlation studies were also supported the old findings.

The results of the analysis of the constraints in adoption of recommended practices in cultivation of coconut in Neyyattinkara taluk are presented in fig.1.

The most important constraint recognized by the coconut farmers was high cost of labour which was followed by low cost of produce, uneconomical holding size and lack of proper knowledge. The farmers agreed that the other constraints were of lesser importance. The non availability of skilled labour and as well as lack of drainage were considered as the least important constraints. These results agreed with the findings of by Vijayakumar (1983), Prasannan (1987), Muliyar (1993) and Sakeer (1994). Mahadik *et al.,* (2009) opined that the low adoption of recommendations was due to lack of knowledge, shortage of labour and high cost and non-availability of inputs. Jnanadevan (2013) reported on the high labour cost, shortage of farm labour, high cost of fertilizers and difficulty in getting skilled plant protection workers as constraints in adoption of recommended management practices in coconut in Kerala. The present investigation supported the above findings.

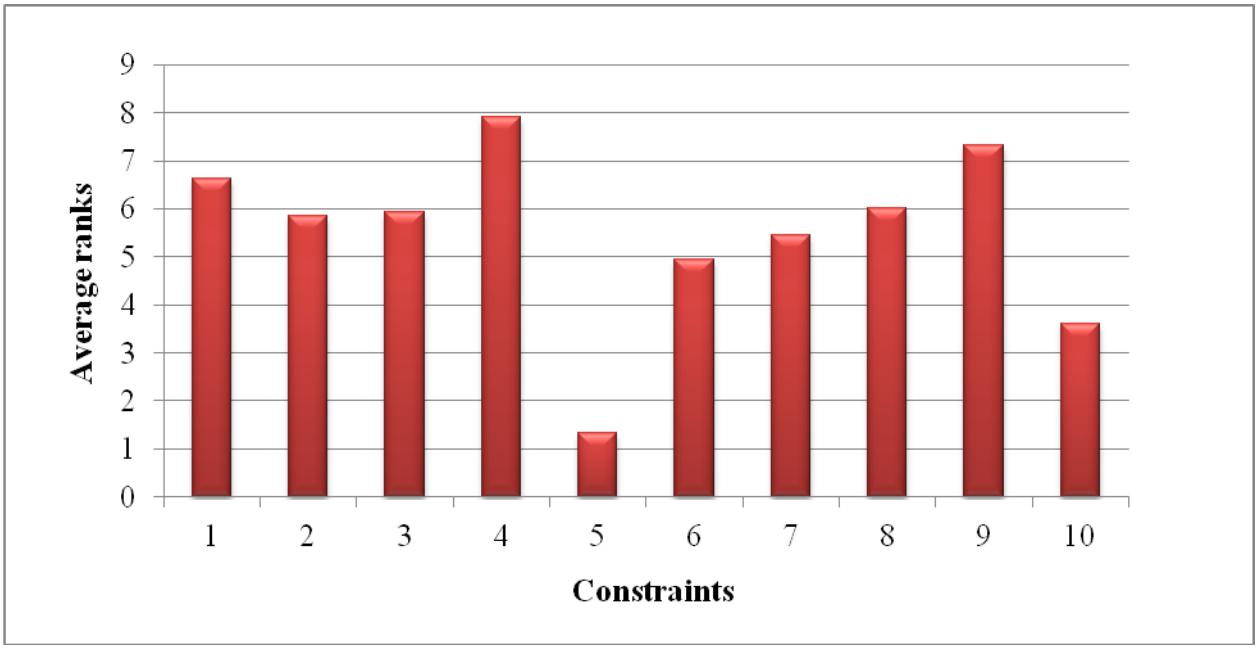

Fig.1. Ranking of the constraints in adoption of recommended practices in cultivation of coconut (lowest values indicate higher ranking).

Constraints - x axis

Average ranks - y axis

1: Non availability of plant protection chemicals

2: High cost of plant protection chemicals

3: Lack of irrigation facilities

4: Lack of drainage

5: High cost of labour

6: Uneconomical holding size

7: Lack of proper guidance

8: Not aware of current dose of chemicals and fertilizers

9: Non availability of skilled labour

10: Cost of produce is low

The technologies including integrated pest management and value addition developed for increasing the productivity and income, respectively in coconut through research and development by the research institutes have to be transferred to the coconut growers. The constraints have to be properly addressed to attract farmers to take up coconut farming and bolster up the economy of the state.

5.2 Field evaluation of newer generation insecticides and botanicals to control the rhinoceros beetle in coconut.

The results of the field experiments to control the rhinoceros beetle conducted in Perumpazhuthoor, Chenkal, Kottukal and Thirupuram panchayats of Neyyattinkara taluk are discussed here under.

After cleaning the crowns of the experimental palms, five insecticides and two botanicals mixed with sand were applied thrice *viz.,* May 2012, September 2012 and January 2013. The observations on number of rhinoceros beetles, freshly damaged crowns, spindles, spathes, number of emerged bunches exhibiting infestation and number of emerged bunches uninfested were recorded at 15, 30 and 45 days after (application of) treatments. Based on the pooled analysis of the observations in the four experiments, the efficacy of the treatments in controlling the rhinoceros beetle was ranked. The findings are presented in table 23.

After three rounds of application of treatments, the pooled mean number of rhinoceros beetles (1.22 per five palms) was the lowest in T1-crown cleaning (cc) + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g) treatment (fig. 2) followed by T6-crown cleaning + leaf axil filling crushed neem seed kernel (100 g) + sand (200 g) treatment (1.58 per five palms). Hence the best treatment in this context was T1-cc + cartap hydrochloride 4 G (25 g) + sand (200 g) application.

With regard to the fresh damage in coconut crowns after three applications of treatments, the mean lowest infestation (1.31 per five palms) was recorded in T1-crown cleaning + leaf axil filling of cartap hydrochloride 4 G

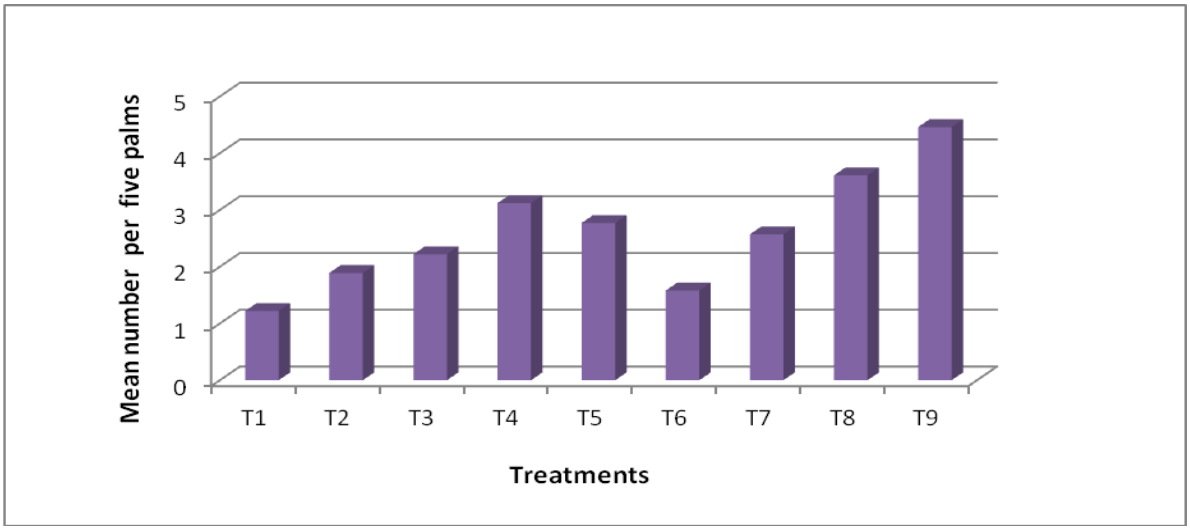

Fig.2. Pooled mean number of rhinoceros beetles after three applications of insecticides and botanicals.

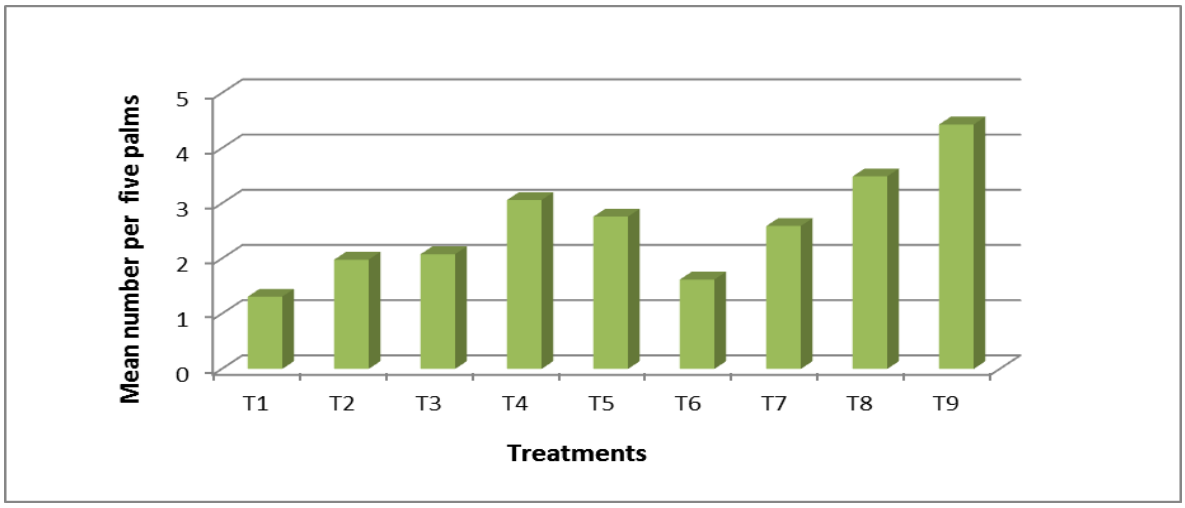

Fig. 3. Mean number of coconut crowns freshly damaged after three applications of insecticides and botanicals.

T1 – Cc + Cartap hydrochloride 4 G (25 g) + sand (200 g) leaf axil filling.

T2 – Cc + Carbosulfan 6 G (25 g) + sand (200 g) leaf axil filling.

T3 – Cc + Fenvalerate 0.4 DP (50 g) + sand (200 g) leaf axil filling.

T4 – Cc + Chlorpyriphos 1.5DP (50 g) + sand (200 g) leaf axil filling.

T5 – Cc + Fipronil 0.3 G (100 g) + sand (200 g) leaf axil filling.

T6 – Cc + Crushed neem seed kernel (100 g) + sand (200 g) leaf axil filling.

T7 – Cc + Chopped tobacco leaves (100 g) + sand (200 g) leaf axil filling.

T8 – Farmers' practice (only crown cleaning)

T9 – Untreated

Cc – Crown cleaning

Table 23. Ranking of insecticide and botanical treatments based on efficacy in controlling rhinoceros beetle*.

(Mean of four experiments)

Treatments	Y1	Rank	Y2	Rank	Y3	Rank	Y4	Rank	Y5	Rank	Overall rank (based on efficacy)
T1-**Cc Cartap hydrochloride 4 G (25 g) + sand (200 g) - leaf axil filling.	1.22	**1**	1.31	**1**	1.51	**1**	7.22	**1**	0.54	**1**	**1**
T2-**Cc Carbosulfan 6 G (25 g) + sand (200 g) -leaf axil filling.	1.89	**3**	1.98	**3**	2.60	**5**	11.10	**2**	1.15	**3**	**3**
T3-**Cc Fenvalrate 0.4 DP (50 g) + sand (200 g) - leaf axil filling.	2.22	**4**	2.08	**4**	2.66	**7**	12.21	**4**	1.23	**4**	**4**
T4-**Cc Chlorpyriphos 1.5 DP (50 g) + sand (200 g) - leaf axil filling.	3.12	**7**	3.06	**7**	2.57	**4**	14.99	**6**	1.99	**7**	**7**
T5-**Cc Fipronil 0.3 G (100 g) + sand (200 g) - leaf axil filling.	2.77	**6**	2.76	**6**	2.64	**6**	14.99	**7**	1.73	**6**	**6**
T6-**Cc Crushed neem seed kernel (100 g) + sand (200 g)- leaf axil filling.	1.58	**2**	1.62	**2**	1.76	**2**	11.11	**3**	0.90	**2**	**2**
T7-**Cc Chopped tobacco leaves (100 g) + sand (200 g)- leaf axil filling.	2.57	**5**	2.59	**5**	2.55	**3**	14.44	**5**	1.64	**5**	**5**
T8-Farmers' practice (Only crown cleaning)	3.61	**8**	3.49	**8**	3.28	**8**	31.10	**8**	2.65	**8**	**8**
T9-Untreated	4.46	**9**	4.43	**9**	4.26	**9**	40.55	**9**	3.74	**9**	**9**

Y1 - Mean number of rhinoceros beetle
Y2 - Mean number of coconut crowns freshly damaged
Y3- Mean number of freshly damaged spindles
Y4- Mean percentage of spathes freshly damaged
Y5- Mean number of emerged bunches exhibiting infestation
*** In five palms**
**** Crown cleaning**

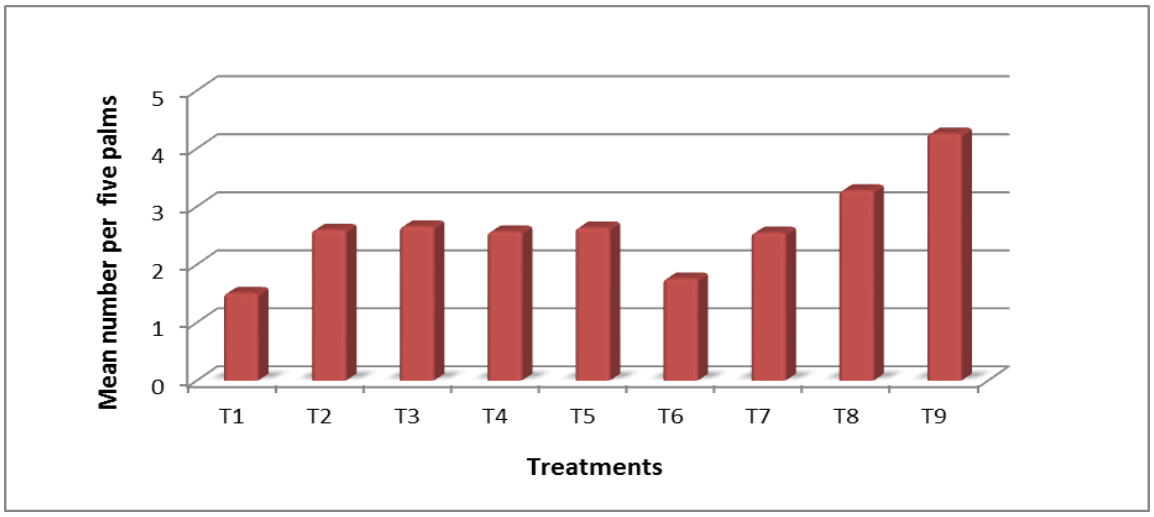

Fig.4. Mean number of coconut spindles freshly damaged after three applications of insecticides and botanicals.

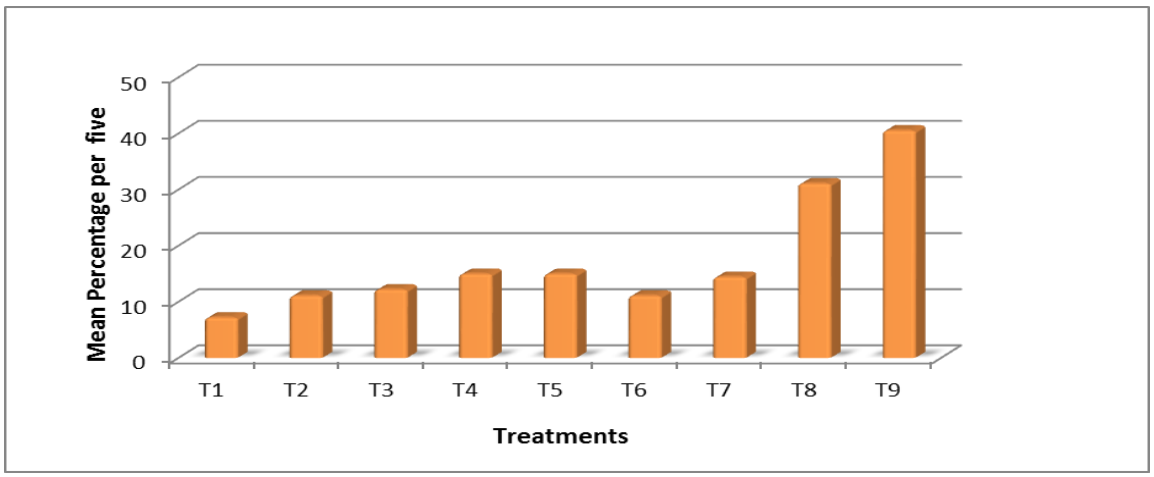

Fig.5. Percentage of coconut freshly damaged spathes after three applications of insecticides and botanicals

T1 – Cc + Cartap hydrochloride 4 G (25 g) + sand (200 g) leaf axil filling.

T2 – Cc + Carbosulfan 6 G (25 g) + sand (200 g) leaf axil filling.

T3 – Cc + Fenvalerate 0.4 DP (50 g) + sand (200 g) leaf axil filling.

T4 – Cc + Chlorpyriphos 1.5DP (50 g) + sand (200 g) leaf axil filling.

T5 – Cc + Fipronil 0.3 G (100 g) + sand (200 g) leaf axil filling.

T6 – Cc + Crushed neem seed kernel (100 g) + sand (200 g) leaf axil filling.

T7 – Cc + Chopped tobacco leaves (100 g) + sand (200 g) leaf axil filling.

T8 – Farmers' practice (only crown cleaning)

T9 – Untreated

Cc – Crown cleaning

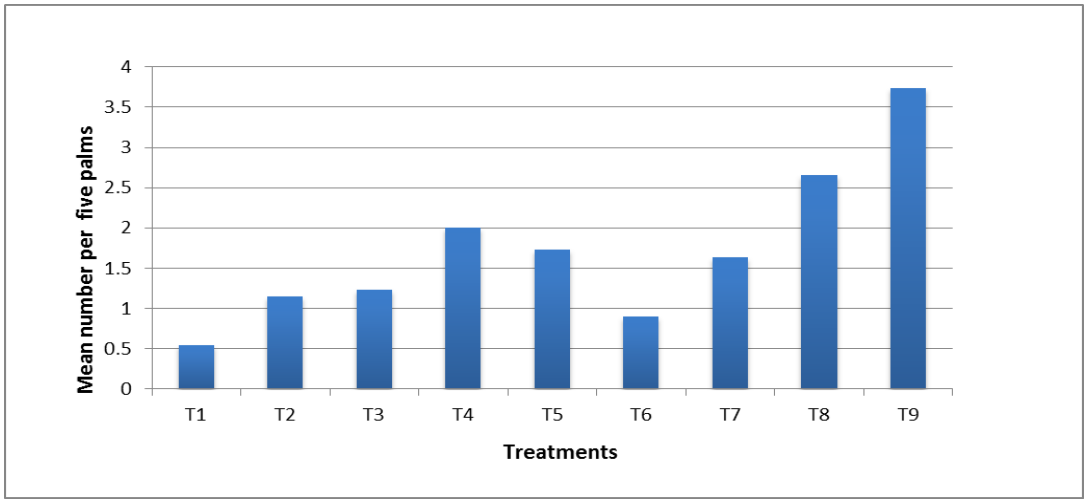

Fig. 6. Mean number of emerged bunches exhibiting fresh infestation by rhinoceros beetle forty five days after three application of treatments.

T1 – Cc + Cartap hydrochloride 4 G (25 g) + sand (200 g) leaf axil filling.

T2 – Cc + Carbosulfan 6 G (25 g) +sand (200 g) leaf axil filling.

T3 – Cc + Fenvalerate 0.4 DP (50 g) + sand (200 g) leaf axil filling.

T4 – Cc + Chlorpyriphos 1.5DP (50 g) + sand (200 g) leaf axil filling.

T5 – Cc + Fipronil 0.3 G (100 g) + sand (200 g) leaf axil filling.

T6 – Cc + Crushed neem seed kernel (100 g) + sand (200 g) leaf axil filling.

T7 – Cc + Chopped tobacco leaves (100 g) + sand (200 g) leaf axil filling.

T8 – Farmers' practice (only crown cleaning)

T9 – Untreated

Cc – Crown cleaning

(25 g) + sand (200 g) treated palms (fig. 3). This was followed by T6-cc + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) treatment (1.62 per five palms). The best treatment in reducing fresh damage to crown was obtained in T1-cc + leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g).

A similar trend was obtatined with regard to the effect of treatments on fresh damage to coconut spindles (fig. 4). The best treatment in reducing fresh damage to spindles was obtained in T1-cc + leaf axil filling of cartap hydrochloride 4G + sand (200 g) followed by T6-cc + crushed neem seed kernel (100 g) + sand (200 g).

Perusal of the results on effect of treatments on fresh damage to spathes (fig. 5) indicated that T1-cc + leaf axil filling of cartap hydrochloride 4G (25 g) + sand (200 g) was the most effective in reducing the damage. This was followed by T2-cc + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g) and the third best treatment was T6-cc + leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g). This result was more important as the damage to the spathes was more crucial compared to damage of spindle and leaf by the beetle.

The impact of three applications of treatments on the infestation in emerged bunches was assessed by observing the damage 45 DAT (fig. 6). In this context, the best three treatments in order of effectiveness were T1-crown cleaning (cc)+ leaf axil filling of cartap hydrochloride 4 G (25 g) + sand (200 g), followed by T6-cc + leaf axil filling + crushed neem seed kernel (100 g) + sand (200 g) and T2-cc + leaf axil filling of carbosulfan 6 G (25 g) + sand (200 g).

Based on the efficacy of the treatments in containing the rhinoceros beetle in the field experiments, it was found out that the best treatment was crown cleaning of the palm followed by filling of the innermost three leaf axils with cartap hydrochloride 4 G (25 g) + sand (200 g) mixture in May, September and January. The best botanical treatment after crown cleaning was crushed neem seed kernel (100 g) + sand (200 g). These two treatments can be recommended in an integrated pest management schedule against the rhinoceros beetle.

Scientists like Nirula *et al.,* (1951), O'Connor (1957), Menon and Pandalai (1958), Kurian and Pillai (1964), Mariau (1967), as well as the KAU (1982, 1983) have advocated the application of organochlorine insecticides like BHC + sand mixture in the leaf axils to control the rhinoceros beetle. Similarly, the application of other pesticides belonging to cyclodiene, carbamate, organophosphorous and synthetic pyrethroid groups have been evaluated against the rhinoceros beetle in coconut and oil palm by other workers. Hitherto most of the insecticides tested were extremely dangerous (red label) and are not in use in Kerala. Leaf axil filling of coconut palms with Sevidol 8 G + sand was earlier recommended by Nair *et al.,* (1997) and KAU (2007). However this insecticide is not available in the market at present. Application of chlorpyriphos dust two to three g admixed with sand on the collar region in coconut seedlings is being recommended against the rhinoceros beetle by Josephrajkumar *et al.,* (2012). However in the present investigation, chlorpyriphos dust + sand ranked only as the seventh best among the nine treatments in controlling the beetle.

In this context, the recommendation of a new chemical insecticide, cartap hydrochloride and botanical, crushed neem seed kernel against the rhinoceros beetle are relevant. The effectiveness of cartap or nereistoxin placed in tissue bags in leaf axils in coconut was established earlier by Hean (2004). Cartap hydrochloride is a systemic insecticide with stomach and contact action. It is a nicotinergic acetylcholine blocker, causing paralysis by blocking transmission of impulses in the central nervous system. It is recommended for the control of chewing and sucking insects including beetles in cereals, pulses, vegetables, tea etc. Therefore cartap hydrochloride can be recommended against the rhinoceros beetle. It has been proved that neem has a more or less ideal toxicity and safety profile as an insect management agent. It has repellent, antifeedant, growth regulation and ovicidal action. It is safe, eco friendly and conserves natural enemies. This is invaluable for use in the coconut crown where a number of predatory spider fauna keep the sucking pests at bay. Hence botanicals like neem can be considered as an important component in IPM. The findings on the

effectiveness of neem seed kernel in the present study were in tune with the recommendations of Chandrika *et al.,* (2001), KAU (2007, 2011) and TNAU Expert System (2013). Based on tests with newer chemical insecticides, Mohan and Josephrajkumar (2013) have advocated the use of chlorantriniliprole (Ferterra) or chlorpyriphos (Chlori dust) six G plus 250g sand for leaf axil filling in coconut. Therefore it could be concluded the use of a chemical insecticide like cartap hydrochloride or botanical like crushed neem seed kernel is effective in managing the rhinoceros beetle.

The ravages of pests like the rhinoceros beetle are only one of the several problems confronting profitable cultivation of coconut in Kerala. Due to the constraints discussed earlier and other issues, the yield realized is about 30 to 40 per cent of the potential under ideal management conditions. Over the past two decades, there has been a shift to other crops like rubber in the State. The demand for resources and the changing demographic profile has added pressure on the scarce resources including land.

In the present scenario, coconut based income generating production systems have to be developed. It is imperative that the constraints that stand in the way of profitable cultivation of coconut have to be mitigated. It should be realized that integrated pest and disease management (IPDM) is a sub system of the coconut farming system and not a separate entity. In the coconut farming systems which include homesteads, pests like rhinoceros beetle can be contained only by area wide pest control campaigns. This can be brought with active participation of the farmers, public and institutions in the target area which calls for social engineering on a wide scale. Trainings have to be imparted and the skills of personnel and labour honed to monitor the pests, assess the damages caused and conduct integrated pest management in coconut. The results of the present investigations will be a small contribution to the technology required for the above endeavours.

The future line of work can include the study of the pharmacology, toxicity, safety and bioefficacy of newer insecticides with novel mode of action and botanicals against the pests of coconut. The findings would play a pivotal role in area wide integrated pest management strategies in coconut based farming systems.

SUMMARY

6. SUMMARY

The coconut is an important and invaluable perennial crop cultivated in various agro ecological systems and provides income and subsistence to the farming community in Kerala. The productivity of the palm is hampered by a number of constraints. One of the important problems encountered in profitable cultivation of coconut is the infestation by a number of pests. Among these, the rhinoceros beetle, *Oryctes rhinoceros* L. is a key pest. The information on the profile of coconut gardens, crop husbandry practices and constraints in coconut cultivation is scanty. Not only is the information on the present status of the beetle and its extent of infestation limited, there is a paucity of pesticide recommendations to control the pest. To address these issues, the present investigations were taken up in Neyyattinkara taluk in 2012-2013. Studies were conducted to assess the intensity of damage caused by the rhinoceros beetle in coconut and evolve management measures using new generation insecticides and botanicals.

A survey was conducted in 2012 in four panchayats *viz.,* Chenkal, Perumpazhuthoor (midland), Thirupuram and Kottukal (coastal) encompassing 40 coconut farmers. Four field experiments were conducted in 2012-2013 in farmers' coconut gardens to assess the efficacy of new generation insecticides and botanicals in controlling the rhinoceros beetle. The salient findings of the studies evaluated are summarized below.,

- In the four panchayats surveyed, 55.00 per cent of the farmers were above the age group of fifty years. 32.50 per cent of the farmers completed SSLC whereas 27.50 per cent had completed pre-degree.

- 45.00 per cent and 30.00 per cent of farmers have grown coconut palms in an area of 50 to 100 cents and less than 50 cents, respectively. 72.50 per cent of farmers have grown coconut palms in garden land and the rest in wetland.

- 87.50 per cent of the palms surveyed belonged to the West Coast Tall (WCT) and only 5.00 per cent were hybrids.55.00 per cent of the coconut palms were above 40 years old. 82.50 per cent of the farmer's coconut gardens yielded less than 40 nuts per palm per year.
- Recommended spacing of 7.5m x 7.5m was followed only by 20 per cent of the farmers. 12.50 per cent of the farmers' coconut gardens were irrigated.
- Majority of the farmers (62.50 per cent) used cow dung manure which was the most preferred. 35.00 per cent of the farmers applied less than the recommended dose of fertilizers. 45.00 per cent of the farmers surveyed did not apply any chemical fertilizer.
- 32.50 per cent of farmers practised field sanitation to prevent breeding of the beetles whereas 27.50 per cent of the farmers practised crown cleaning.
- Hooking out the beetles using beetle hook was practised by 10.00 per cent of the farmers.
- Application of neem cake mixed with sand in leaf axils was undertaken by 20.00 per cent of the farmers.
- 10.00 per cent of the farmers placed naphthalene balls and covered the same with the sand in the inner most two leaf axils. None of the farmers applied pesticide dust with sand or any other chemical pesticides to control the rhinoceros beetle.
- None of the farmers adopted pest management in an integrated manner against the rhinoceros beetle.
- The percentage of palms infested and as well as fresh infestation by the rhinoceros beetle ranged from 72.00 to 83.00 and 23.64 to 27.27, respectively in the different panchayats.

- The percentage of leaves and as well as central spindles infested by the beetle ranged from 35.86 to 56.41 and 27.00 to 42.00, respectively in the different panchayats.
- The percentage of fresh spathes and as well as dried spathes infested by the rhinoceros beetle ranged from 13.07 to 15.61 and 7.07 to 8.85, respectively in the different panchayats.
- The percentage of palms infested by coreid bug, eriophyid mite and mealy bugs was 34.00, 35.00 and 10.00, respectively.
- Twelve and 32.00 per cent of the palms exhibited bud rot and leaf rot disease symptoms, respectively.
- The rhinoceros beetle did not infest any crop other than coconut.
- The damage to leaves, spathes and central spindles infested by rhinoceros beetle was positively correlated with minimum temperature and number of rainy days in Perumpazhuthoor and Thirupuram panchayats.
- The number of rhinoceros beetle males and females collected in the pheromone traps per fortnight ranged from 6.33 to 7.00 and 5.66 to 6.00 respectively during May 2012 to July 2012
- The rhinoceros beetle population collected in aggregation pheromone traps was positively correlated to maximum, minimum temperature and number of rainy days.
- The most important constraint recognized in adoption of recommended practices in coconut was high cost of labour. This was followed by low cost of produce, uneconomical holding size and lack of proper guidance.
- Crown cleaning followed by three applications of cartap hydrochloride 4G (25 g) plus (200 g) sand or crushed neem seed kernel (100 g) plus (200 g) sand mixture in the innermost three leaf axils during May, September and January was the best in controlling the rhinoceros beetle. This was followed by crown cleaning plus leaf axil filling of crushed neem seed kernel (100 g) + sand (200 g) mixture. Control measures involving either

cartap hydrochloride or crushed neem seed kernel can be recommended as part of an integrated pest management strategy to contain the beetle.

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7. REFERENCES

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MANAGEMENT OF THE RHINOCEROS BEETLE (*Oryctes rhinoceros* L.) ON COCONUT USING NEW GENERATION INSECTICIDES AND BOTANICALS.

by

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ABSTRACT

A study entitled "Management of the rhinoceros beetle (*Oryctes rhinoceros* L.) using new generation insecticides and botanicals" was conducted in four panchayats of Neyyattinkara taluk during 2012 to 2013. The objectives were to assess the intensity of damage caused by the rhinoceros beetle in coconut and evolve management measures using new generation insecticides and botanicals to control the beetle.

The survey was conducted in 40 coconut farmers' gardens. The most salient findings of the survey were 1) WCT variety of palm was predominant in the area (87.50 %). 2) 55 per cent of the palms were above 40 years. 3) 82.50 percent of palms gave less than 40 nuts per year. 4) the recommended dose of manures and fertilizers were applied by only 20 percent of the farmers. 5) only 12.50 percent of the farmers irrigated the palms. 6) about 30.00 of the farmers conducted only field sanitation and crown cleaning and 7) no farmer undertook pest management measures in an integrated manner against the rhinoceros beetle.

In the four panchayats, the mean percentage of palms infested, fresh infestation on palms, leaves infested, central spindles infested, fresh spathes infested, dried spathes infested by the rhinoceros beetle were 77.50, 25.89, 45.33, 35.50, 14.43 and 7.55, respectively.

Apart from the rhinoceros beetle infestation, the percentage of palms infested by coreid bug and eriophyid mite was 34.00 and 35.00 per cent respectively. Thirty two per cent of the palms exhibited symptoms of leaf rot disease.The rhinoceros beetle did not infest any crop other than coconut.

The rhinoceros beetle population and its damage to leaves, spathes and central spindles of the coconut palms were positively correlated to minimum temperature and number of rainy days.

The mean population of male and female rhinoceros beetles caught per fortnight in aggregation pheromone traps ranged from 6.33 to 7.00 and 5.66 to 6.00 respectively during May 2012 to July 2012.

The most important constraint in adoption of recommended practices in coconut cultivation was high cost of labour followed by low cost of produce, uneconomical holding size and lack of proper guidance.

Four field experiments were conducted in farmers' fields to evaluate the effect of selected new generation chemical insecticides and botanicals for the control of rhinoceros beetle in coconut. The results indicated that the best treatments included the chemical insecticide, cartap hydrochloride followed by crushed neem seed kernel.

The present investigations brought to focus the crop husbandry practices including plant protection adopted by coconut farmers, constraints, incidence of rhinoceros beetle and its extent of infestation. Based on the study, the following recommendations can be included as part of an Integrated Pest Management strategy against the rhinoceros beetle.

"Crown cleaning followed by three applications of either cartap hydrochloride 4 G (25 g) plus (200 g) sand mixture or crushed neem seed kernel (100 g) plus (200 g) sand mixture in the innermost three leaf axils during April-May, September – October and December-January."

APPENDIX - I

Weather parameters

Period	Temperature (^{o} C)		Humidity (%)		Rainfall (mm)	Number of rainy days
	Maximum	Minimum	Morning	Afternoon		
March-I	31.70	23.30	93.66	64.54	12.00	4
March-II	31.36	22.60	93.46	64.76	10.00	3
April -I	32.65	24.70	91.25	65.40	12.50	3
April -II	30.00	25.45	88.80	73.95	103.90	9
May-I	30.90	25.45	90.50	73.15	25.50	3
May -II	31.48	25.95	91.55	73.20	23.00	2
June -I	31.23	25.10	91.40	72.32	30.00	7
June -II	29.60	23.66	92.30	74.66	42.00	9
July-I	29.55	23.95	87.00	75.60	86.00	9
July-II	29.95	24.55	93.35	75.55	27.50	5

APPENDIX-II

SURVEY OF COCONUT CULTIVATION IN NEYYATINKARA TALUK

1. Panchayat : Coastal(or) midland :
2. Name of the Panchayat :
3. Location of farmers' field :

   Address :

   Ward no :

4. Name of the farmer :
5. Age :
6. Education :
7. Size of holding :
8. Area under coconut palms :
9. Whether wetland or garden land :
10. Yield (nuts/palm/year) in farmers' field :
11. Whether irrigated or not :

Details of plant protection measures undertaken (if any).

a) Cultural	
b) Mechanical	
c) Biological	
d) Organic	
e) Chemicals	

Constraints in adoption of recommended practices in cultivation of coconut

Sl. No.	Constraints	Grade
1	Non availability of plant protection chemicals	
2	High cost of plant protection chemicals	
3	Lack of irrigation facilities	
4	Lack of drainage	
5	High cost of labour	
6	Uneconomical holding size	
7	Lack of proper guidance	
8	Not aware of current dose of chemicals and fertilizers	
9	Non availability of skilled labour	
10	Cost of produce is low	
11	Others (if any)	
	(Constraints will be graded)	

Palm no	Variety	Age of palm	Spacing (mxm)	Cowdung quantity	Green leaves	Compost	Urea	MOP	Factomphos	Mixture	Complexes	Others	Time of application

			Incidence of Rhinoceros beetle (R.b) and its damage (in 10 palms)										
Palm no.	R.beetle infestation		Total no of leaves	No of leaves infested	Total no of spathes	No of spathes infested	No of dried spathes due to R.b	Central spindles infestation		No of adults in pheromone traps	Palms showing infestation	Other pests	Diseases	Other crops infested by R.b
1	No	Yes						No	Yes					
2														
3														
4														
5														
6														
7														
8														
9														
10														